NOVA

1 | 2

TTO

HAVO | VWO
TEXTBOOK

PHYSICS & CHEMISTRY

MALMBERG

NOVA

PHYSICS & CHEMISTRY

1 & 2 HAVO | VWO

Authors

P. van Hoeflaken

R. Tromp

Editors

K. Gibbs

R. Tromp

With help from

Th. Smits

Fourth edition

MALMBERG 's-Hertogenbosch

www.nova-malmberg.nl

Preface

The book that you are holding in your hands right now is for your physics and chemistry course. We cannot explain what those two fields are all about in just a few words. Instead, this book starts with a short description to give you an idea of the subject.

The method
Nova consists of a textbook, digital material and an answer book.

This textbook covers all the teaching material that you have to learn. There are exercises after each section that will help you remember the material and apply it in practice. The exercises are split up into questions on the course material, which are often taken literally from the theoretical parts of the text, plus questions about practical applications. Some questions are marked with an asterisk (*). These are generally a little more difficult.

Each chapter ends with a number of experiments and Test Yourself questions. There is also a section at the back of the book explaining the skills that you will need for this subject.

The V-trainer in the digital material lets you practice your skills.

Basic material, Plus material and Everyday science
You will go through most of the course material in the book together with the rest of the class. This is the basic material that all the pupils have to know.

At the end of each section, you can find the Plus material. You can go through that if you have any spare time left over when you have finished with the basic material. The Plus material is mostly a bit more difficult than the basic material.

At the end of each chapter there is an 'Everyday science' section, an article in which part of the course material is discussed in a situation from daily life or from a scientific context. These also contain a number of exercises.

Working independently
Nova lets you work independently. You can do the exercises in groups or on your own, you can do the research tasks or you can use the Test Yourself pages to check how you are doing. Explanations will sometimes also be given to the whole class at once.

If you work independently, it is a good idea to make a plan. That means that you must write down what you are going to do and when, before you start.

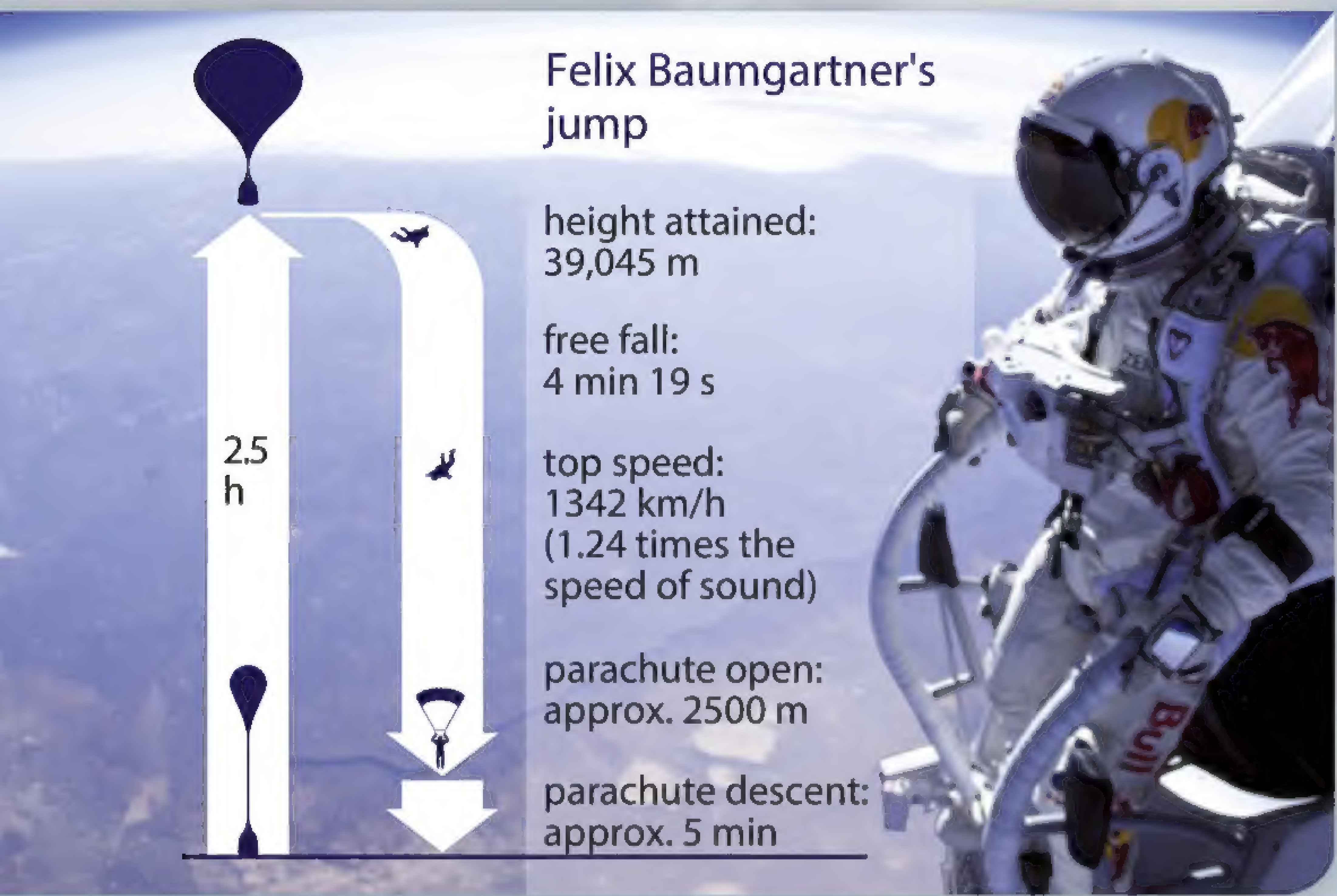
Physics and chemistry are about the world around you. Discovering how that world works is a journey that is both fascinating and exciting. We hope that this book will help you a bit along the way.

We wish you every success!

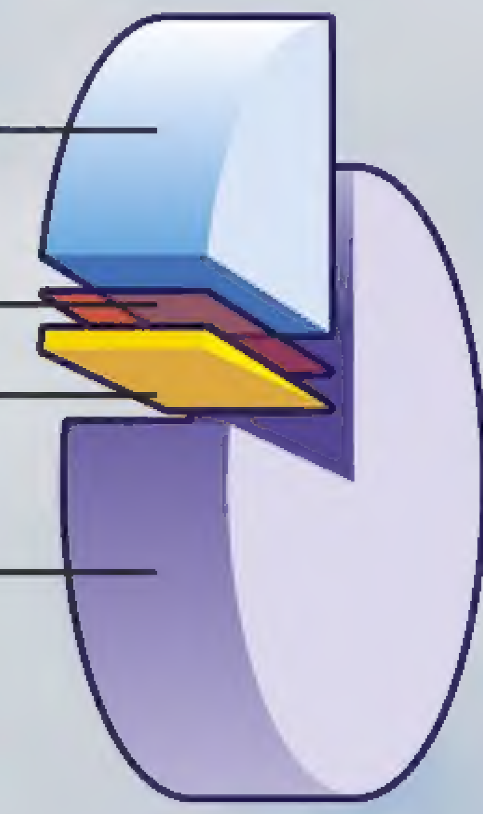
The authors

Contents

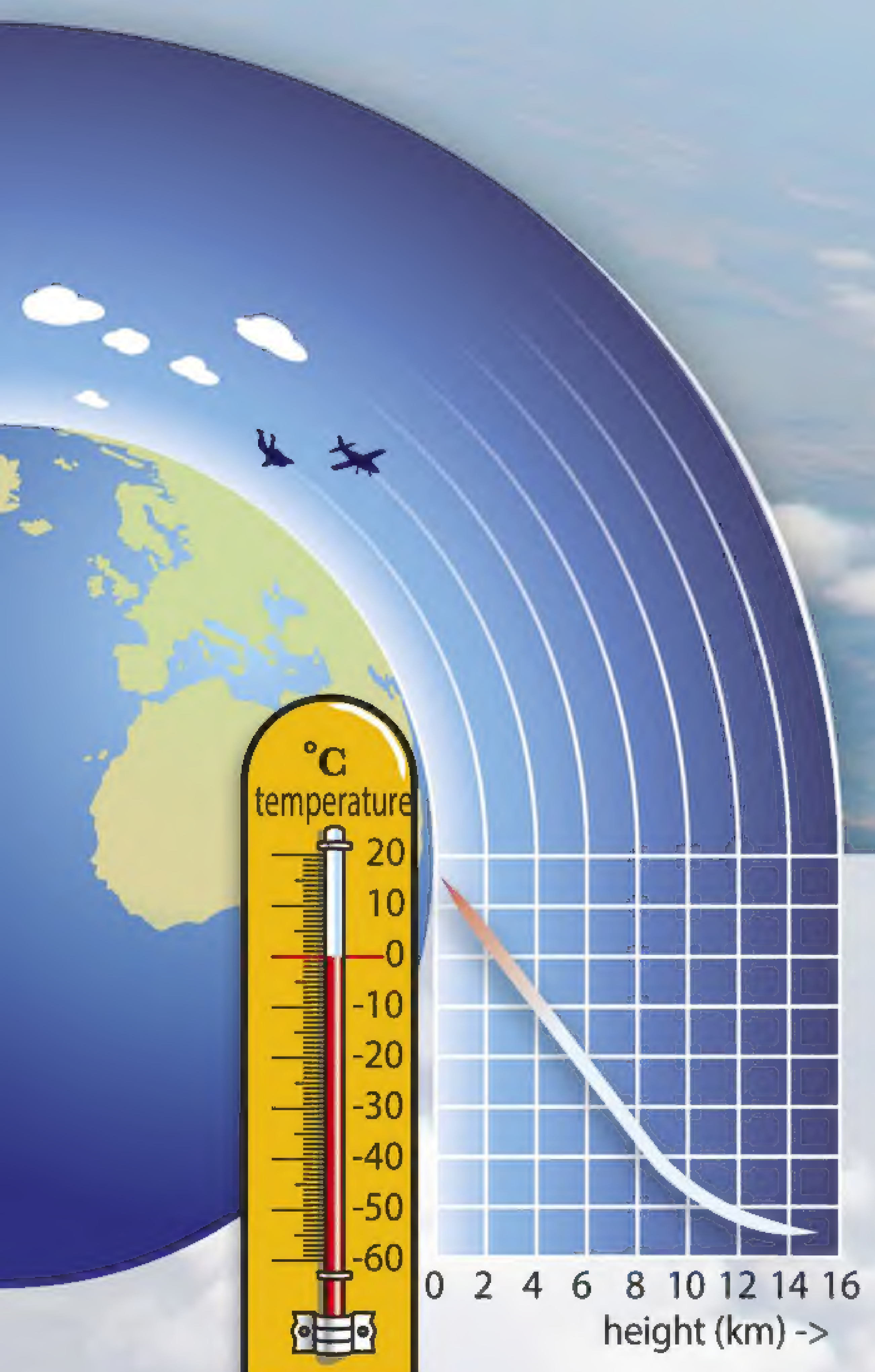
1 Introduction



The composition of air



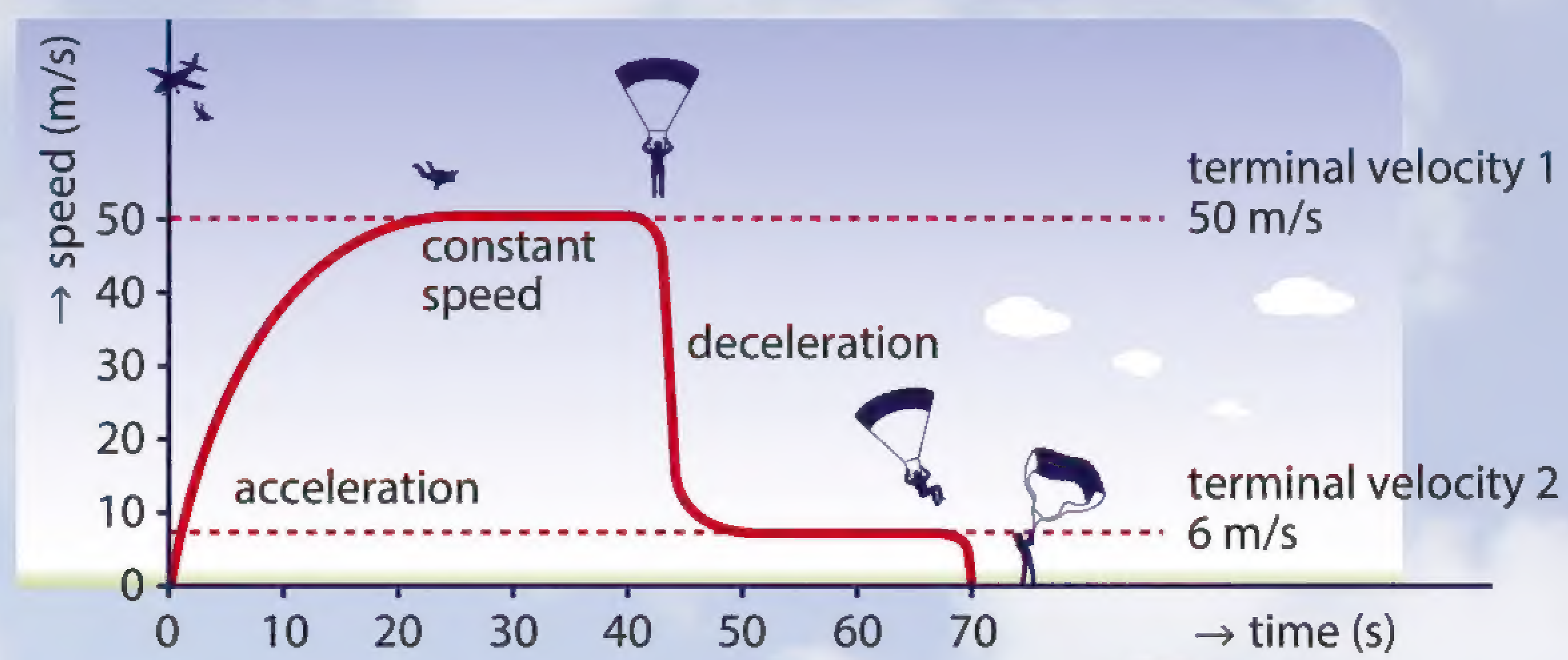
Air is a mixture of nitrogen and oxygen plus small quantities of other gases.



Temperature and height

The higher you go, the colder it gets. At an altitude of 4 km – the height an experienced skydiver jumps out of the plane from – it is bitingly cold.

Fall velocity



What is it like at an altitude of 4 km?

air density	speed of sound	air pressure	temperature	
0.82 g/cm^3	1166 km/h	620 mbar	-11 °C	4 km
1.38 g/cm^3	1224 km/h	1020 mbar	18 °C	sea level

Science:
from discovery to application

▲ figure 1
Your ears don't like it when you drive uphill.

Scientists have made all sorts of discoveries. These discoveries are also applied in a practical way in all kinds of objects and devices. Scientific knowledge is behind almost everything you use, from washing machines to sunglasses.

Doing research

Scientists investigate how the world works. They look at an **effect** and ask what is happening and why it is like that. The sciences are sometimes called the *natural sciences* to distinguish them from the social sciences (like economics and sociology). As a 'natural' scientist, you want to understand the 'nature' of the things around you - the way things fit together and how they work. You want to know more than just *what* happens; you also want to know *why* it behaves that way, rather than some other way.

An effect (or 'phenomenon') is something you can observe. For example, take the uncomfortable feeling you get in your ears when you go up a big hill in a car (figure 1). You notice that, whether you want to or not. As a scientist, you want to know more about this effect. For example, you may investigate:
- whether the speed of the car as it goes uphill makes any difference;
- whether the height of the hill and its steepness make any difference;
- whether people feel anything when they go back down the hill again;
- and so forth.

After you have got a good picture of what causes the effect, you can ask the following question: "Why do you get that sensation in your ears?" Or, to put it another way, "How can that sensation be explained?" That search for an **explanation** is a key aspect of all natural sciences. You are only satisfied when you understand the reasons for an effect.

Science has been around for a long time. Over the course of time, good explanations have been found for all kinds of effects, including the uncomfortable feeling in your ears when you drive uphill. You can read more about this in chapter 4. Even so, there is still more than enough work for young scientists: lots of phenomena are still waiting to be explained.

Thinking up applications

Once you have discovered how an effect works, you can also make use of it. In physics and chemistry you will therefore not only be learning about discoveries that scientists have made. You will also learn about the **applications** of those discoveries.

One of those applications began with a discussion about the 'nature' of air pressure: what creates that pressure? A scientist came up with the idea of taking a barometer, an instrument for measuring air pressure, to the top of a mountain. That led to the discovery that the air pressure depends on the altitude: the higher you go, the lower the air pressure gets.

This discovery was quickly put to use to develop an altimeter, a meter that works out your altitude using the pressure of the air. Modern altimeters still work on this principle. Skydivers in free fall can use this kind of meter to determine when they should open their parachutes.

▲ figure 2
an altimeter on a parachutist's arm

There is a lot more scientific knowledge embodied in a parachutist's equipment. In the parachute itself, of course, but also in the safety helmet, the protective clothing and the sunglasses. Not only the design but also the materials used are the result of many years of research.

Exercise

1 Applications of science can be found everywhere. In this exercise, you will be making a PowerPoint slide with information about one such application.

- **a** Find a good photo of an application. Use one of the photos on pages 10 and 11 or find a suitable photo yourself.
- **b** Put the photo on a PowerPoint slide (landscape orientation) and make sure that it fills the whole slide.
- **c** Search for information about the application and about the scientific knowledge that it utilises. This may be in image form and/or as text.
- **d** Arrange the information that you have found on the slide. Use the picture on pages 6 and 7 as an example.
  Your teacher will tell you how you are going to present your end result to the class.

To be investigated: How does a doctor measure your blood pressure, weight, lung capacity, pulse and respiration rate? What do the measuring instruments look like?

To be investigated: How does the mirror in the telescope work? What is the focal point? What are infrared and ultraviolet radiation? What is a spectrum?

To be investigated: How does a solar panel like this work? How can you store the electrical energy? Why have LED lights been chosen?

To be investigated: What role does oxygen play in a fire? What is needed for a fire to get started? How can a fire be extinguished?

2

Substances

Working with different substances

You use all sorts of substances every day: you put sugar in your tea, wash your hair with shampoo, rinse a glass out with water, spray deodorant on your skin and so forth. Before you can work with substances, you have to be familiar with their properties.

1 Substances in the home

▲ figure 1
A few substances that you might come across at home.

You will find bottles, jars and tins of various substances around the home. Have a look around in the kitchen, the bathroom, the garage, the medicine cupboard, etc. You will find substances such as table salt, sugar, vinegar, baking powder, ammonia, white spirit, motor oil, paracetamol, iodine, and so on (figure 1).

Recognizing substances

Some of these substances look very similar, and so you can't immediately see what substance it is. White spirit, water and alcohol all look just the same, for example. All three are clear, colourless liquids.

Sometimes smelling the substances can help. Lots of substances have a distinctive odour that lets you recognize them immediately. Think of the smell of petrol, for instance, or the smell of chlorine at the swimming pool.

But you do have to be careful: some substances can irritate the mucous membranes of the nose and lungs. So take care when smelling things: take the top off the bottle, wave your hand gently back and forth above the neck and sniff just a little bit of the vapour (figure 2). That will make sure you don't inhale too much of an irritant substance.

Categorizing substances   Experiment 1

The characteristics that let you recognize a substance are called its **properties**. You can use them to distinguish between different substances. Examples of the properties of substances are:
- **odour:** the smell of alcohol is different from the smell of turpentine.
- **colour:** copper is orange-red, gold is yellowish, lead is grey.
- **taste:** sugar tastes sweet, table salt tastes salty.
- **flammability:** petrol is flammable but water is not.

▶ figure 2
The safe way to smell what's in a bottle.

Nova © Uitgeverij Malmberg

When you store substances, you do not just put them all together in the same place. Usually, you store things with similar uses together. This gives you groups of substances, such as foodstuffs, medicines, cleaning agents and fuels.

Substances and safety

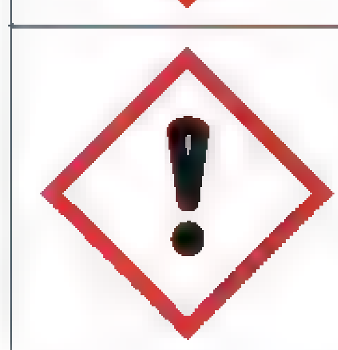
Some substances that are used in the home can be dangerous. Think of methylated spirits, white spirit, bleach, ammonia and all sorts of medicines. A substance can for example be hazardous if:

- you breathe it in;
- you swallow it;
- you get it on your skin, in your eyes or on your clothes;
- it comes close to a flame;
- it is mixed with certain other substances.

This is why there are warnings and labels on the packaging of hazardous substances. The hazards are also indicated by symbols, pictograms known as **hazard symbols**. Figure 3 shows six hazard symbols and their meanings.

Bottles containing hazardous substances often have child-proof lids. These have to be pressed down firmly as you unscrew them.

▶ **figure 3**
Six hazard symbols and their meanings

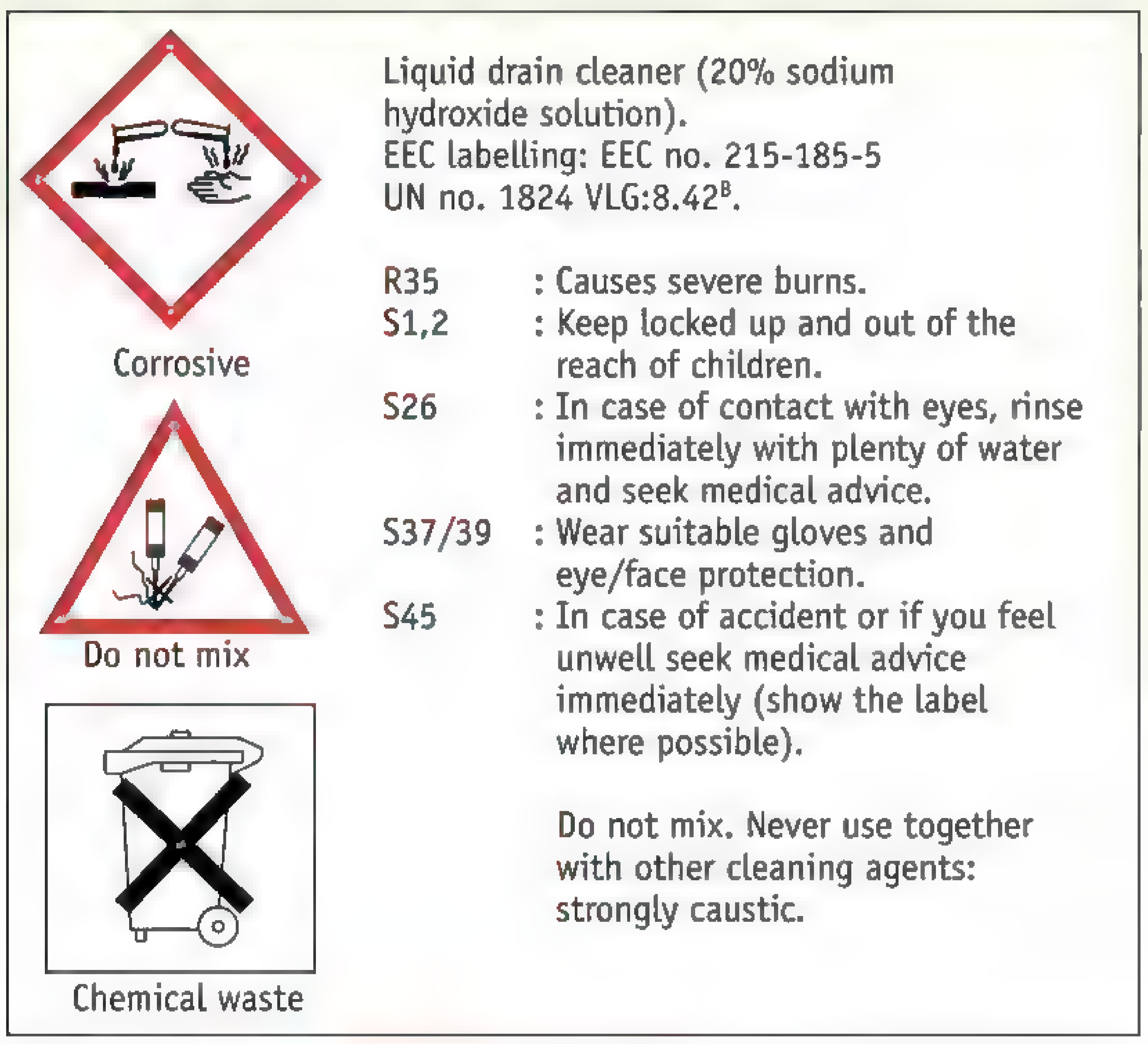
pictogram	meaning + explanation
	**corrosive** can severely affect fabrics, eyes and skin
	**explosive** can be made to explode by a spark or a shock
	**highly flammable** can easily catch fire
	**oxidising** can make flammable substances burn more fiercely
	**toxic** can make you seriously ill or can even be fatal
	**harmful** is harmful and can irritate the skin and eyes

Plus R and S phrases

Figure 4 shows the label on a bottle of drain cleaner. As well as three symbols, the label has a number of R and S phrases. An **R phrase** tells you what hazard you have to be careful about. The R stands for 'risk'. An **S phrase** states the safety precautions that you should take. The S stands for 'safety'.

Drain cleaner is a corrosive liquid. It can severely damage your eyes and skin. The R phrase makes the hazard clear: the substance causes severe burns. The S phrases state suitable safety precautions, such as in S37 and S39: 'Wear suitable gloves' and 'Wear eye/face protection' such as safety goggles.

▼ **figure 4**
The safety information on a drain cleaner label



Manufacturers are not allowed to think up their own R and S phrases; they must stick to an official list instead. A new list will come into force worldwide in 2015: the GHS (Globally Harmonized System of Classification and Labelling of Chemicals). This new list uses H phrases (H for 'hazard') instead of R phrases, and P phrases (P for 'precaution') instead of S phrases.

Exercises

1 Answer the questions below.
- **a** What is meant by the 'properties' of a substance?
- **b** Give four examples of substance properties.

2 Give a distinctive property of:
- **a** copper.
- **b** petrol.
- **c** sugar.
- **d** alcohol.

3 Explain the hazard of:
a a corrosive substance.
b a highly flammable substance.
c an oxidizing substance.

4 Give a distinctive property of:
a vinegar.
b lead.
c olive oil.
d methylated spirits.

5 You can classify substances into groups, such as foodstuffs, cleaning agents, fuels and medicines.
State which group (or groups) each of these substances belongs to.
a ammonia
b butane
c vinegar
d chlorine bleach
e candle wax
f paracetamol
g vegetable oil
h methylated spirits
i turpentine

6 Carl has a bottle of mineral water, a bottle of alcohol and a bottle of white spirits in his shed. The labels on the bottles have become illegible over the course of time. The three bottles look identical too.
a How can he find out which substance is in which bottle?
b What property of the substances can he therefore use to tell them apart?

7 The same substance can occur in forms that look very different.
a What can sugar look like? Think of how sugar is sold.
b What can water look like (for example in various weather conditions)?

*8 If you work with hazardous substances, the rule is that 'prevention is better than cure'. Car drivers who are smoking should therefore put their cigarettes out before filling up with petrol.
State a suitable safety precaution (think one up yourself) for someone who is:
a unblocking a blocked drain with drain cleaner (which is corrosive).
b wiping down a door with ammonia (which is an irritant) before painting it.
c getting grease stains out of his trousers with white spirit (which is highly flammable).

Plus R and S phrases

9 The label of a bottle of methylated spirits has six phrases after circular 'bullets' (•):

- Highly flammable.
- Keep container tightly closed.
- Keep away from sources of ignition. No smoking.
- Harmful if swallowed.
- Keep out of reach of children.
- If swallowed, seek medical advice immediately and show this container or label.

a State whether each phrase is an R phrase or an S phrase.
b Which phrases give precautions for avoiding accidents?
c Which phrase tells you what you should if something does go wrong?
d What hazard symbol should be put on this label?

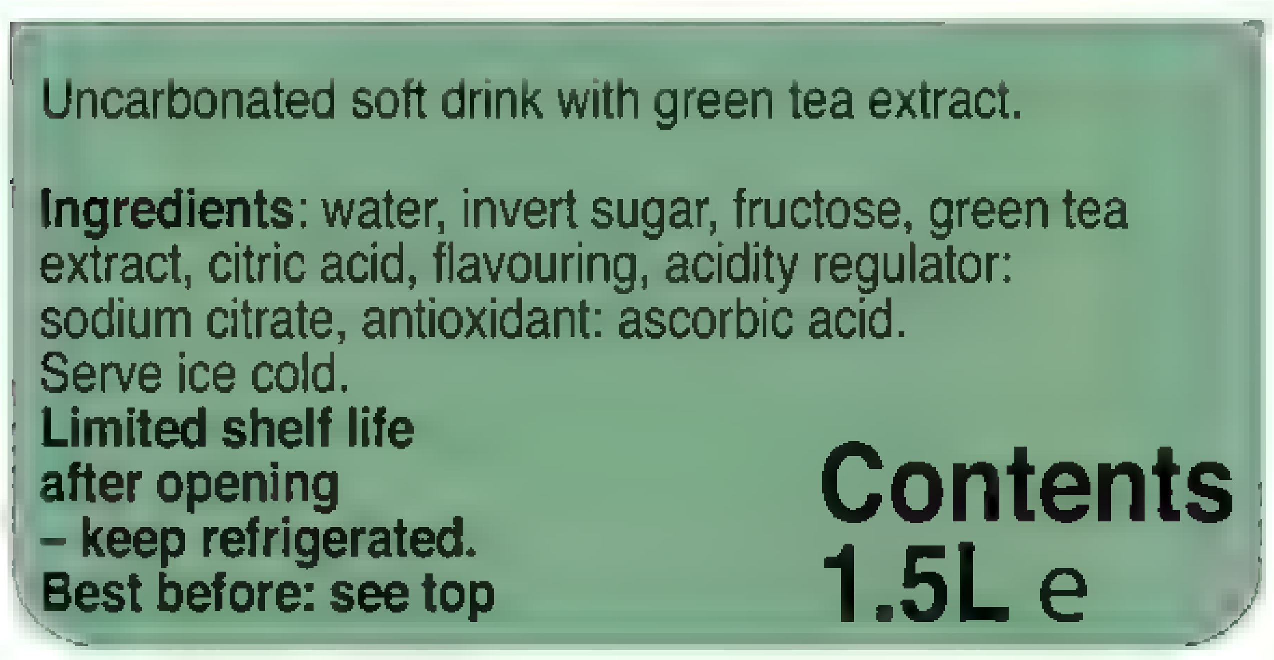
10 Search for an overview of all S phrases (or P phrases) on the Internet. Find and make a note of an S phrase (or P phrase) that you might come across on:
a the packaging of a corrosive substance.
b the packaging of a toxic substance.
c the packaging of a highly flammable substance.
d the packaging of an oxidizing substance.

2 Pure substances and mixtures

Most of the substances that you will find at home are mixtures. You'll see that straight away if you look at the packaging of a foodstuff or a medicine. It states the various substances that are in the product, i.e. the list of ingredients. Sometimes the ingredients themselves are mixtures too.

Mixtures and pure substances

Figure 5 shows the list of ingredients in a bottle of ice tea. Water is the most important ingredient – as in any soft drink – and it is therefore listed first. The ice tea also contains sweeteners, acids, aromas and flavourings. There is also a preservative in it. All these substances are stated separately on the label.



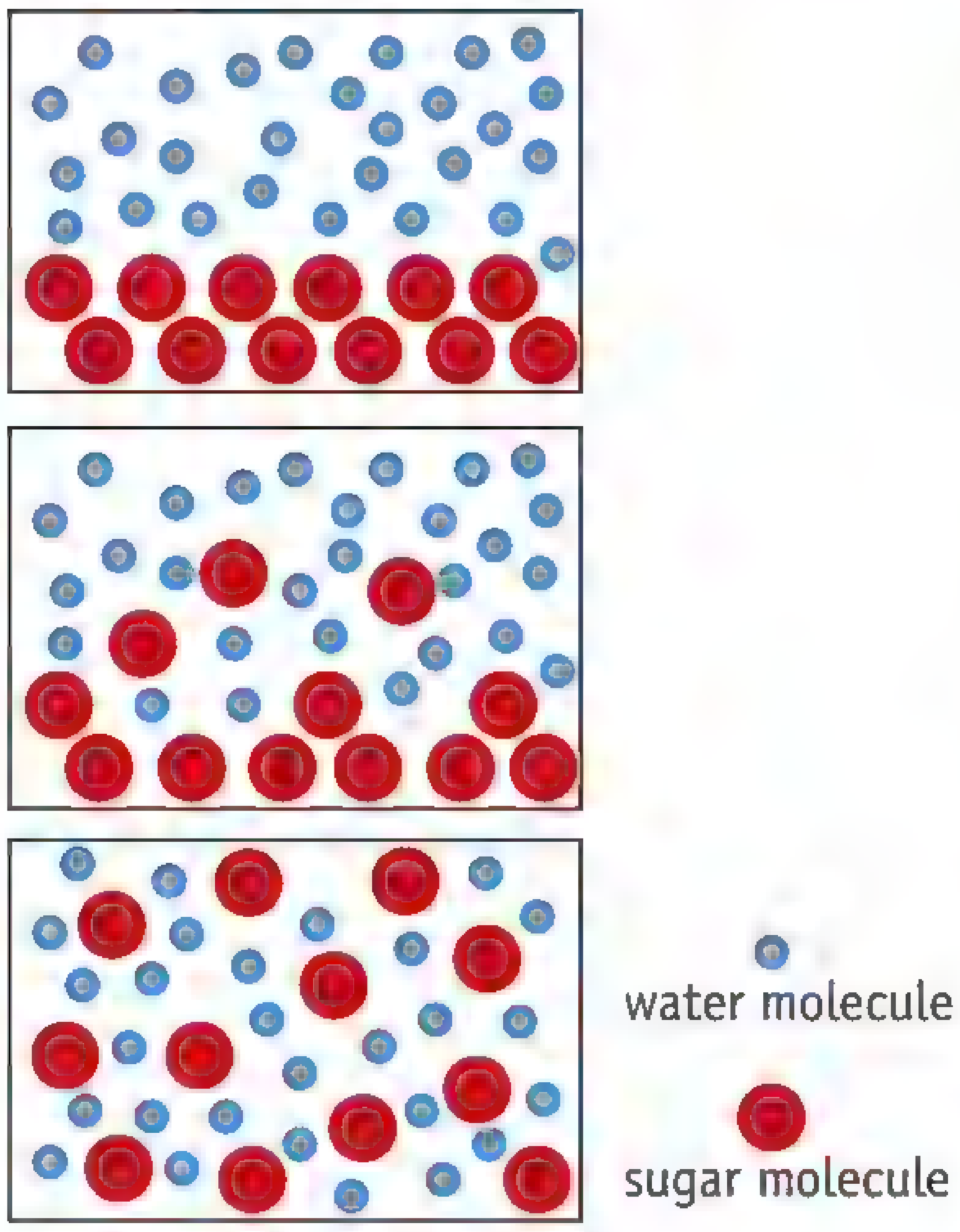
▶ figure 5
the list of ingredients on a bottle of ice tea

You will not find many substances around the home that are not mixtures. Substances that are not mixtures are called **pure substances**. An example of a pure substance is granulated sugar. A bag of sugar contains only sugar – there are no other substances mixed in with it. Table salt that has not been iodized is also a pure substance.

After a lot of experimenting, physicists came to the conclusion that substances are made up of extremely small particles. These particles are called **molecules**. A pure substance (a pure chemical compound) consists of just a single type of molecule: pure water contains only water molecules, pure sugar contains only sugar molecules and pure alcohol contains only alcohol molecules. A mixture contains different kinds of molecules.

Solutions

If you put sugar in a hot cup of tea and stir it for a moment, you will see that the sugar grains disappear. We say that the sugar has dissolved in the tea. The mixture that you get is known as a **solution**. Water is the **solvent** in this case and sugar is the **dissolved substance**. You can tell that the sugar hasn't actually disappeared if you taste the tea, though: it now tastes sweet.



▲ figure 6
When sugar dissolves, the sugar molecules become distributed among the water molecules.

When a solid substance like sugar is dissolved, the molecules of the substance are scattered around between the molecules of the solvent. Figure 6 shows you what is happening. After a while, the solid substance is completely dissolved. The molecules of the dissolved substance are then surrounded on all sides by molecules of the solvent.

Many of the substances that you can find at home are solutions. Examples are tea, energy drinks and soft drinks, deodorant, perfumes and shampoo.

Recognizing solutions   Experiment 2

Solutions are clear and always stay perfectly mixed. A coke is a good example. The soft drink does not change if you leave it in the cupboard: after a year, it is still just as thoroughly mixed as the day that you bought it. If a mixture is cloudy (opaque) and separates out over the course of time, then it cannot be a solution.

Paint, for instance, is not a solution. Instead, it is a **suspension:** a liquid in which a very fine powder is floating. Because paint separates out – the powder will settle at the bottom of the tin in time – you have to stir paint before using it. If you see 'shake well before use' or 'stir before use' on a substance's packaging, then it is probably a suspension.

A bottle of mineral water may say that it contains 'pure mineral water'. In chemical terms, though, mineral water is not a pure substance. There are all kinds of substances dissolved in the water, as you can see on the label. The word 'pure' in this case means that the water is not contaminated with harmful substances or bacteria. You can drink it with no risk to your health.

The size of a molecule

Molecules are incredibly small. Their dimensions are therefore measured in nanometres. One nanometre is a billionth of a metre: 1 nm = 0.000000001 m. The diameter of a water molecule is about 0.15 nanometres. A sugar molecule is a bit bigger, with a diameter of 1 nanometre.

▼ figure 7
The steps in size from a water molecule to a table tennis ball and from a table tennis ball to the Earth are the same.

▲ figure 8
filtering coffee

The following example gives you an idea of just how small a single water molecule is. Suppose you could blow up a ping-pong ball to the size of the Earth. If you could 'blow up' a water molecule by the same amount, it would then be the size of the table tennis ball. The Earth is about 300 million times the size of a ping-pong ball, which is in turn about 300 million times bigger than a water molecule (see figure 7).

Because molecules are so small, they can fit through very small gaps. This can be seen if you pour a solution through a coffee filter. Nothing remains in the filter. Molecules can pass through the filter by going through small gaps between the paper fibres. Even though the gaps are too small for the human eye to see, they are huge holes compared with the size of the molecules.

Extraction and filtering Experiments 3 and 4

If you add hot water to ground coffee (figure 8), the aroma and flavour components in the coffee dissolve in the water. In other words, you are using the hot water to get the aromas and flavourings out of the coffee. This is known as **extraction** (literally 'pulling out'). You are extracting the aroma and flavour substances using hot water as the solvent.

To remove the coffee grounds, you use a **filter**. The coffee can flow through the holes in the filter easily. The coffee grounds can't, because the granules are much too big to pass through the holes in the filter. The coffee therefore ends up in the coffee pot and the grounds remain behind in the filter. The coffee is referred to as the **filtrate** and the coffee grounds are the **residue**.

▲ figure 9
Many perfumes consist of aromatic substances that are dissolved in alcohol.

Plus Alcohol as a solvent

Some substances such as fats and oils do not dissolve in water. For these substances, you need a different solvent such as alcohol or white spirit. You can use alcohol for degreasing things, for example. The grease on the object dissolves in the alcohol, and you can then wipe the alcohol off with a cloth.

Alcohol is used as a solvent in all sorts of products (see figure 9). Examples are perfumes, deodorants and certain types of ink and paint. Some pens have 'alcohol-based' ink. When you write or draw with the pen, the alcohol evaporates and the dyestuffs remain. You can then smell the alcohol clearly.

The substance that is generally called 'alcohol' is referred to in chemistry as **ethanol**. If a label mentions ethanol, it means 'ordinary' alcohol, the same substance as is in beer and wine. Chemists use the word alcohol as a collective name for a whole group of compounds. To them, ethanol is one of the many different alcohols.

Exercises

11 What is the chemical term for a substance:
- **a** that is made up of different sorts of molecules?
- **b** that is made up of only one kind of molecule?

12 State whether each of the following statements is true or false.
- **a** When you make coffee, you are using water as a solvent.
- **b** Solutions are always colourless (just like water).
- **c** A suspension does not remain perfectly mixed over the course of time.
- **d** A suspension is clear: you can see through it.
- **e** Suspensions and solutions are not pure substances.
- **f** Most substances in daily life are mixtures.

▲ **figure 10**
Charlotte's experiment

13 Give words to fill in the blanks:
- **a** Ground coffee beans contain a lot of different aromas and ......
- **b** These substances dissolve when you pour .... over the ground coffee.
- **c** The substances that do not dissolve in water remain in the ......
- **d** The freshly made coffee in the coffee pot is called the ......
- **e** The used coffee grounds in the filter are called the ......

14 Say whether you think each of the following substances is a solution or a suspension. State your reasons.
- **a** tea with sugar
- **b** orange juice
- **c** an energy drink such as Red Bull
- **d** yoghurt

15 Charlotte puts a spatula-tip of white powder into a test tube. She adds distilled water and shakes it. Figure 10 shows you what the contents of the test tube look like, just after shaking it (figure 10a) and one hour later (figure 10b).
- **a** How can you tell that the white powder was not dissolved?
- **b** What kind of mixture was obtained by shaking?
- **c** What happened to the white powder after an hour?

▲ **figure 11**
Making tea = extraction and filtering.

16 A tea bag is a quick way of making a cup of tea (figure 11).
In this situation, what is:
- **a** the solvent?
- **b** the filter?
- **c** the filtrate?
- **d** the residue?

17 Filters often get clogged up and the liquid can then no longer flow through them.
- **a** Give an explanation for this.
- **b** Will a filter get clogged up more easily by a coarse powder or a fine powder?

***18** Sometimes you can separate the substances in a mixture by filtering the mixture.
- **a** Explain:
  - why this does work with a suspension.
  - why this does not work with a solution.
- **b** The holes in paper filters have diameters of 10 to 25 micrometres.
  1 micrometre = one millionth of a metre = 0.000001 m.
  Suppose someone was making a model of water molecules in a filter. In their model, the water molecules are the size of ping-pong balls. How big will the gaps in the filter be if they are represented at the same scale? Show your calculations.

Plus Alcohol as a solvent

19 Ethanol is a component of all sorts of products.
- **a** What is the everyday name for ethanol (the name used on many product labels)?
- **b** Why is water not suitable for use as a solvent for perfumes, although ethanol is?
- **c** A site with household tips says, "You can remove greasy stains from fabrics by dabbing them with spirits such as vodka."
  Explain why the stains disappear when dabbed with vodka, but not if clean water is used.
- **d** Glands in your skin produce greases that protect the skin from drying out.
  Explain why your skin can feel dry if it comes into contact with ethanol a lot.

20 Search the Internet for information about methylated spirits. Use it to answer the questions below.
- **a** What are the uses of methylated spirits?
- **b** What must you definitely not do with methylated spirits?
- **c** Why is methylated spirits also called 'denatured alcohol'?
- **d** What is the main component of methylated spirits?
- **e** What other substances are there in methylated spirits?
- **f** Explain the reasons why each of these substances is added to methylated spirits.

Nova © Uitgeverij Malmberg

3 Mass and volume

Pancakes
(with yeast, for the whole class)
***
1.5 kg flour
30 grams salt
6 eggs
60 grams yeast
2.7 litres milk
240 grams butter

▲ figure 12
a recipe for pancakes

You often need a specific quantity of a substance – no more, and no less. Recipes, for instance, often say how much of each ingredient you need to use (figure 12). It is also extremely important that medicines contain the correct amount of the active compound.

Measuring a quantity of a substance

There are various ways of measuring out substances. You will have noticed this when you work in the kitchen. Scales are useful for solid substances such as flour and sugar. Liquids such as water and milk are often measured out in a measuring jug. Similar measuring instruments are used in physics and chemistry.

Mass

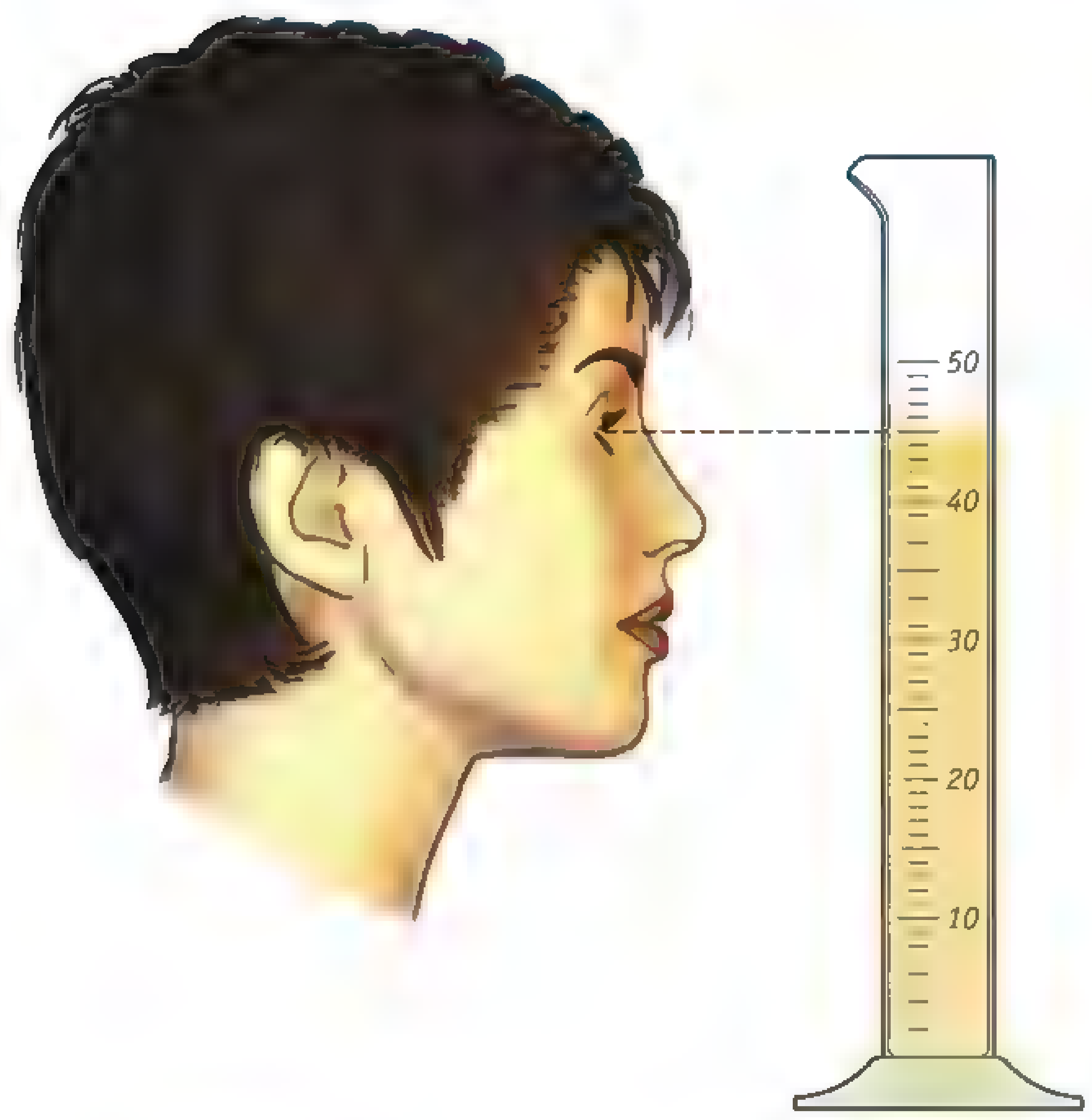
Scales allow you to determine the **mass** of a quantity of a substance (figure 13). The mass is a measure of the quantity of the substance: twice as much mass means that you have twice as much of the substance, and so forth. If you double the mass when weighing out sugar, the number of sugar molecules will be doubled as well.

▲ figure 13
Working with scales.

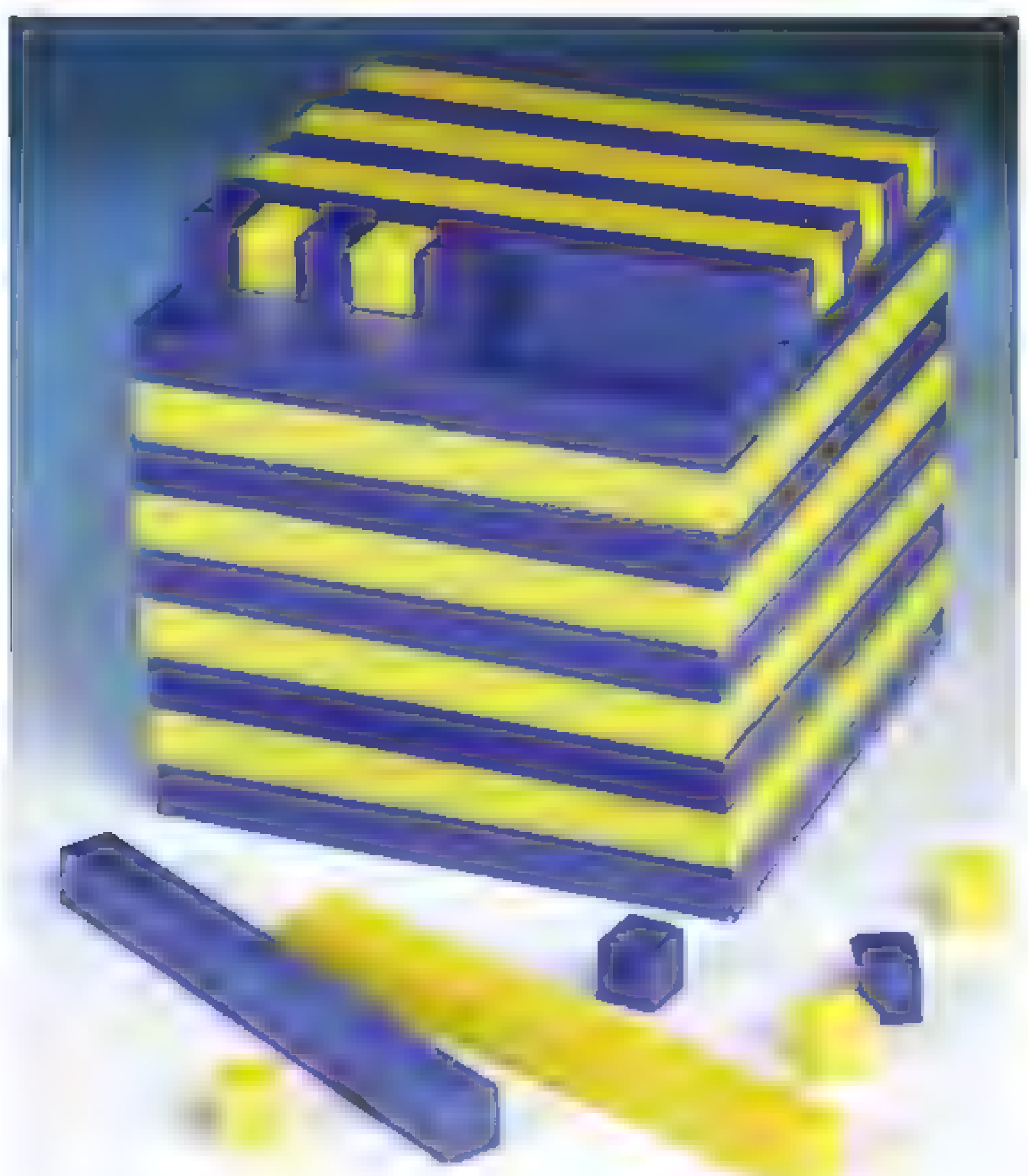
The unit of mass is the kilogram (kg). We say that the **variable** called mass is measured in **units** of kilograms. Various larger and smaller units are derived from the kilogram, such as the ton (t), the gram (g) and the milligram (mg). Remember:
- 1 t = 1000 kg
- 1 kg = 1000 g
- 1 g = 1000 mg

Mass and weight are two different things in physics. The mass is defined as how much substance there is in an object. The weight is the force that the object exerts on your hands (if you lift it up) or on the floor (when you put it down). How much the object weighs depends not only on its mass (i.e. the amount of substance in it) but also on the strength of gravity.

In everyday life, you don't see any difference between mass and weight because the pull of gravity is more or less the same everywhere on the Earth. But that is no longer true if you leave the Earth. Astronauts are well aware that their weight can vary enormously, whereas their mass – the amount of substance making up their bodies – stays the same.



▲ figure 14
How to read a measuring cylinder.



▲ figure 15
1 dm^3 = 1000 cm^3

Volume

A measuring cylinder lets you determine the **volume** of a quantity of liquid. You then know how much space the liquid takes up. The volume is a measure of the quantity of a substance: twice as much volume means that you have twice as much of the substance, and so forth. Figure 14 shows you how to read a measuring cylinder: with your eyes at the same level as the surface of the liquid. This lets you find the volume of liquid in millilitres (mL).

The millilitre (mL) is a derived unit based on the litre (L). It is one thousandth of a litre. This unit is only used for liquids and gases. In other cases, you use the cubic decimetre (dm^3). However, the litre and the cubic decimetre mean exactly the same thing:
1 L is the same as 1 dm^3 = the space occupied by a cube with sides of 1 dm.
1 millilitre is the same as 1 cm^3: the space occupied by a cube with sides of 1 cm (see figure 15).

Remember:
- 1 m^3 = 1000 dm^3 = 1000 L
- 1 dm^3 = 1000 cm^3 = 1 L
- 1 cm^3 = 1 mL

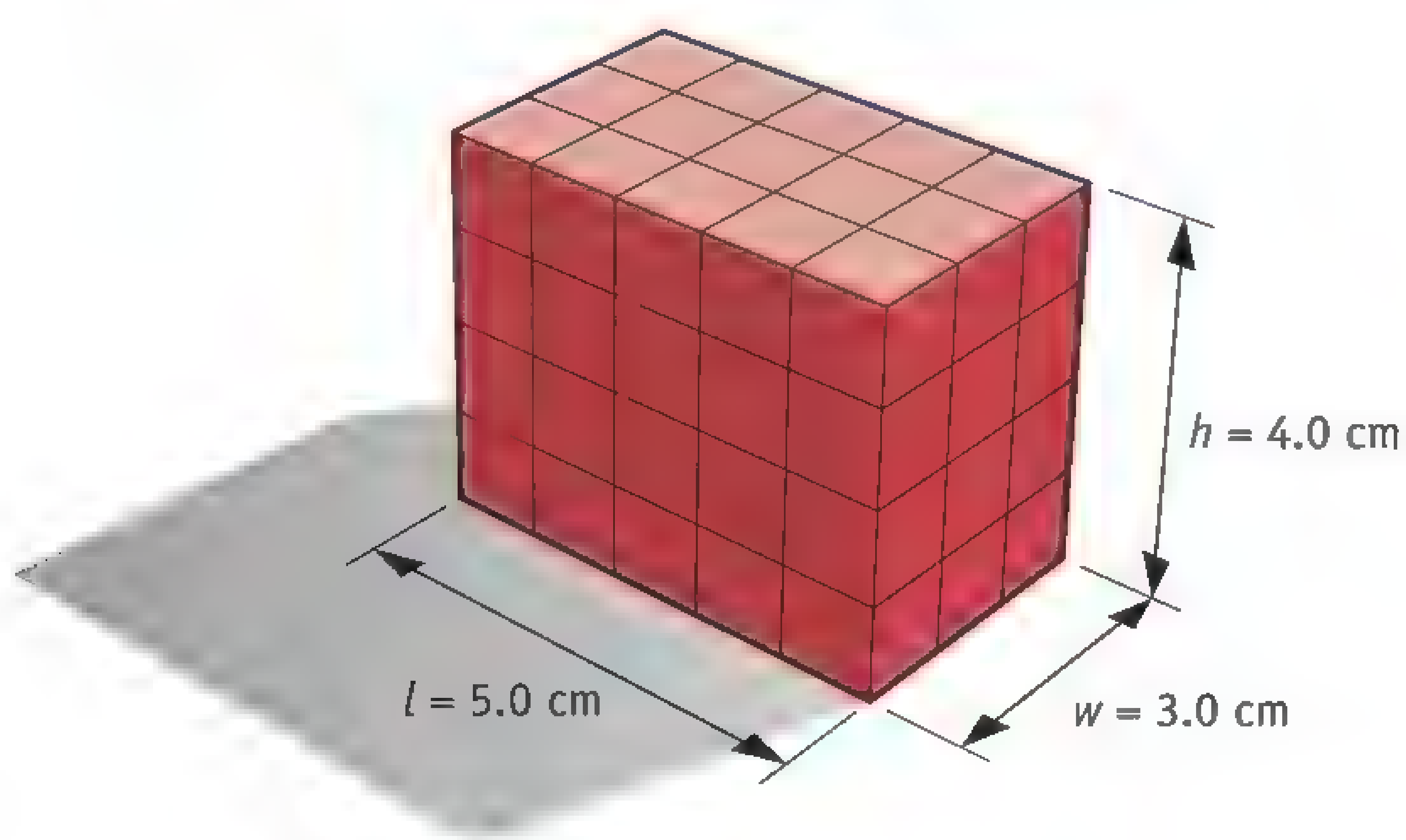
Calculating the volume   Experiment 5

Objects take up a specific amount of space. That space is referred to as the volume of the object. You can calculate the volume of a rectangular object using the formula volume = length × width × height (figure 16), or in symbols:

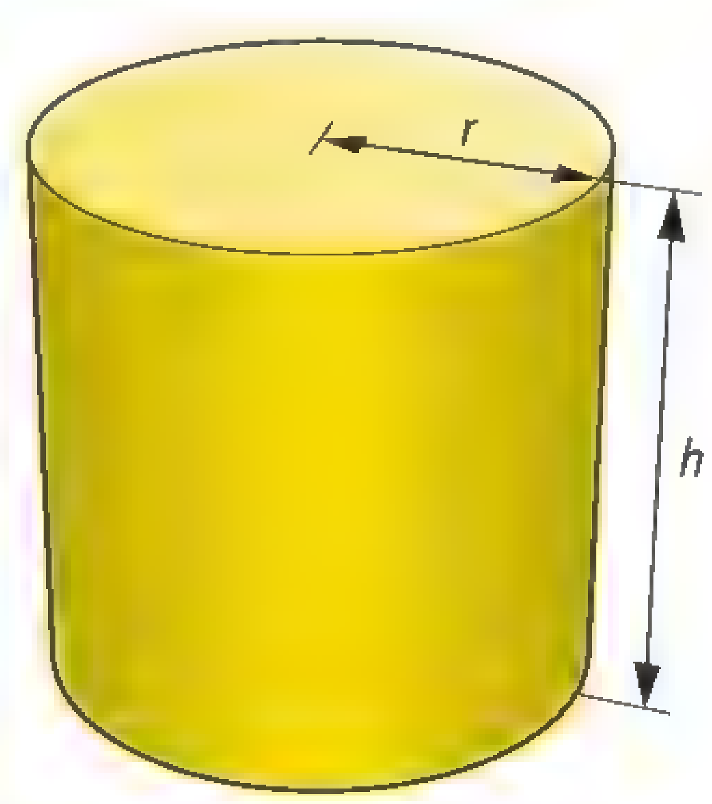
$$V = l \cdot w \cdot h$$

You can calculate the volume of a cylinder using the formula volume = pi × radius × radius × height (figure 17), or in symbols:

$$V = \pi \cdot r^2 \cdot h$$



▲ figure 16
the volume of a rectangular object: $V = l \cdot w \cdot h$



▲ figure 17
the volume of a cylinder: $V = \pi \cdot r^2 \cdot h$

If you use dimensions (l, w, h and r) in centimetres (cm), then you will calculate the volume in cubic centimetres (cm^3). If you use dimensions of decimetres (dm), then you will calculate the volume in cubic decimetres (dm^3).

Worked example 1
Calculate the volume of a roll of biscuits: The roll is 20 cm high and has a diameter of 11.2 cm. Round the answer off to a whole number.

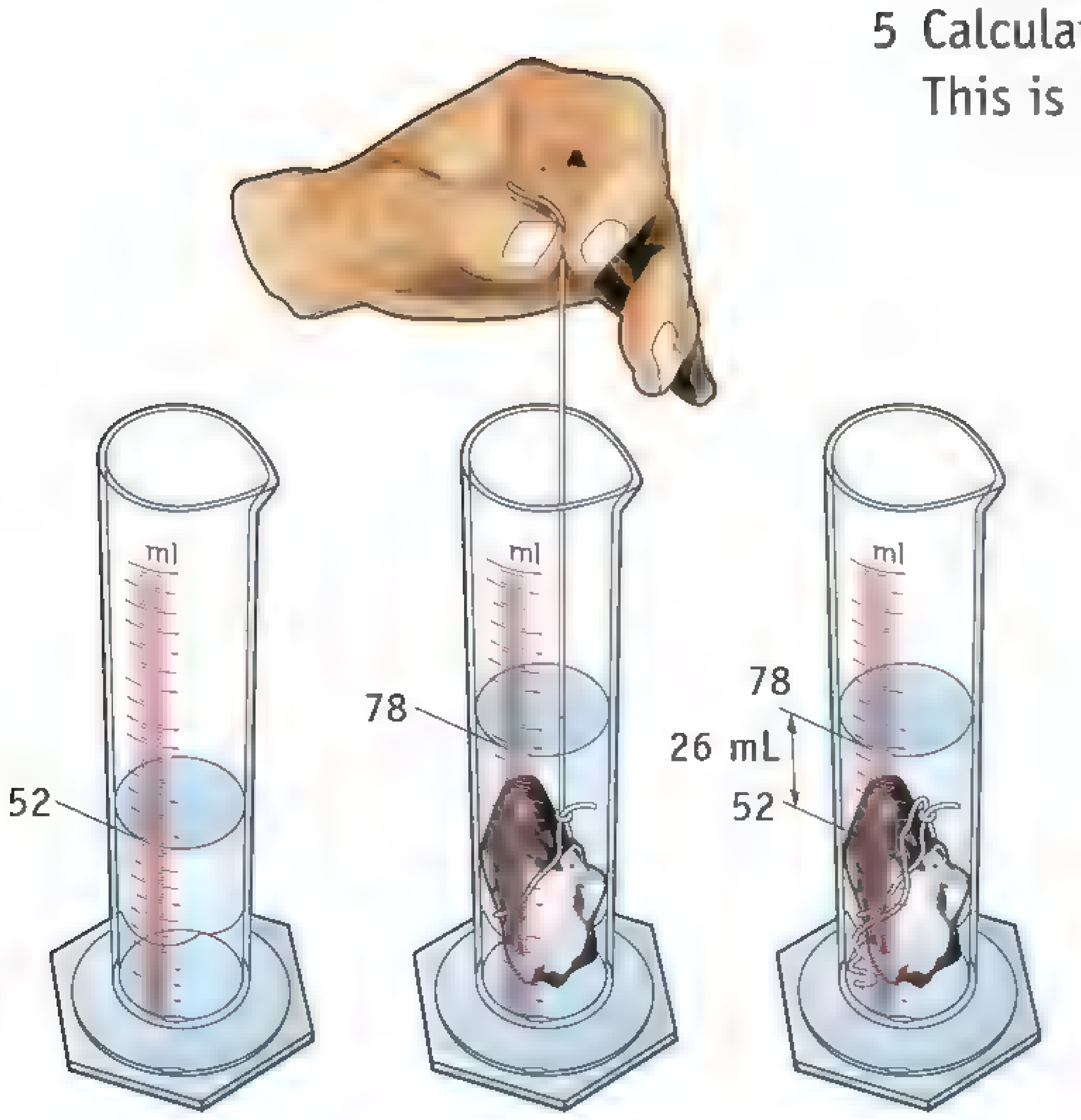
data $r = 11.2 : 2 = 5{,}6$ cm
$h = 20$ cm

required $V = ?$

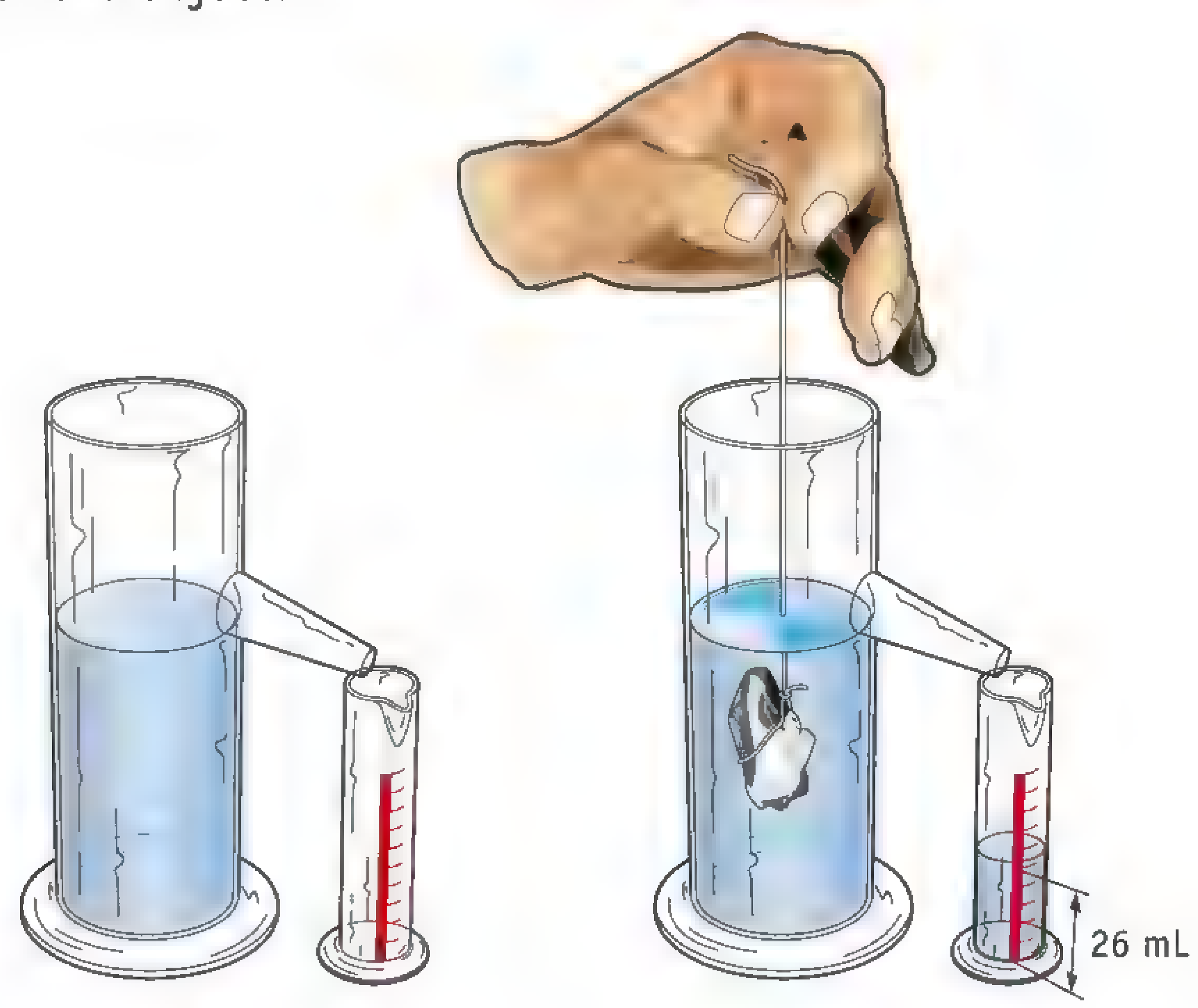
working $V = \pi \cdot r^2 \cdot h$
$= \pi \times (5.6)^2 \times 20$
$\approx 1970\ cm^3$

Determining the volume experimentally Experiment 6

The volume of an irregularly shaped object such as a pebble can be determined by the **immersion method** (figure 18). It works like this:
1 Fill a measuring cylinder with water to a given level.
2 Read the level of the water.
This is called the **starting level.**
3 Lower the object carefully into the water.
The object must be completely submerged.
4 Read the level of the water again.
This is called the **finishing level.**
5 Calculate the finishing level minus the starting level.
This is the volume of the object.



▲ figure 18
This is how the immersion method works.



▲ figure 19
The immersion method using an overflow cylinder.

An overflow cylinder makes it even easier (figure 19). You have to fill the overflow cylinder with water right up to the overflow spout. When you submerge the object in it, the quantity of displaced water that will flow out through the spout has the same volume as the object. If you use a measuring cylinder to catch the water that flows out, you can determine the volume.

Plus The composition of mixtures

▲ figure 20
the information on a bottle of mineral water

Sometimes it is important to know the exact composition of a mixture. You not only want to know which substances there are in the mixture, you also want to know in what quantities. There are various ways of indicating that.

For drinking water, the **concentrations** of the substances dissolved in it are often given in milligrams per litre. The mineral water in figure 20, for instance, contains 106 mg of calcium per litre. This means that one litre of this mineral water will contain 106 mg calcium. A 500 mL bottle will therefore contain 106 : 2 = 53 mg calcium.

The alcohol content of alcoholic drinks is often given by percentage volume (% vol). Beer, for example, has an alcohol content of 5% by volume. This means that 1 L beer contains 50 mL alcohol. A bottle of 30 cL (= 300 mL) therefore contains 5% of 300 mL = 15 mL alcohol.

Exercises

21 Explain how you can determine:
- **a** the mass of a quantity of a solid substance.
- **b** the volume of a quantity of a liquid substance.
- **c** the volume of a rectangular block.
- **d** the volume of a pebble.

22 Copy and complete:
- **a** 1 kg = ... g
- **b** 1 g = ... mg
- **c** 1 m^3 = ... dm^3
- **d** 1 dm^3 = ... cm^3
- **e** 1 L = ... mL
- **f** 1 mL = ... cm^3

23 See 'Skills 3' at the back of the book.
Many packages state the mass of the contents in grams or kilograms.
Copy table 1 and fill in the missing data.

▼ **table 1** contents in grams and kilograms

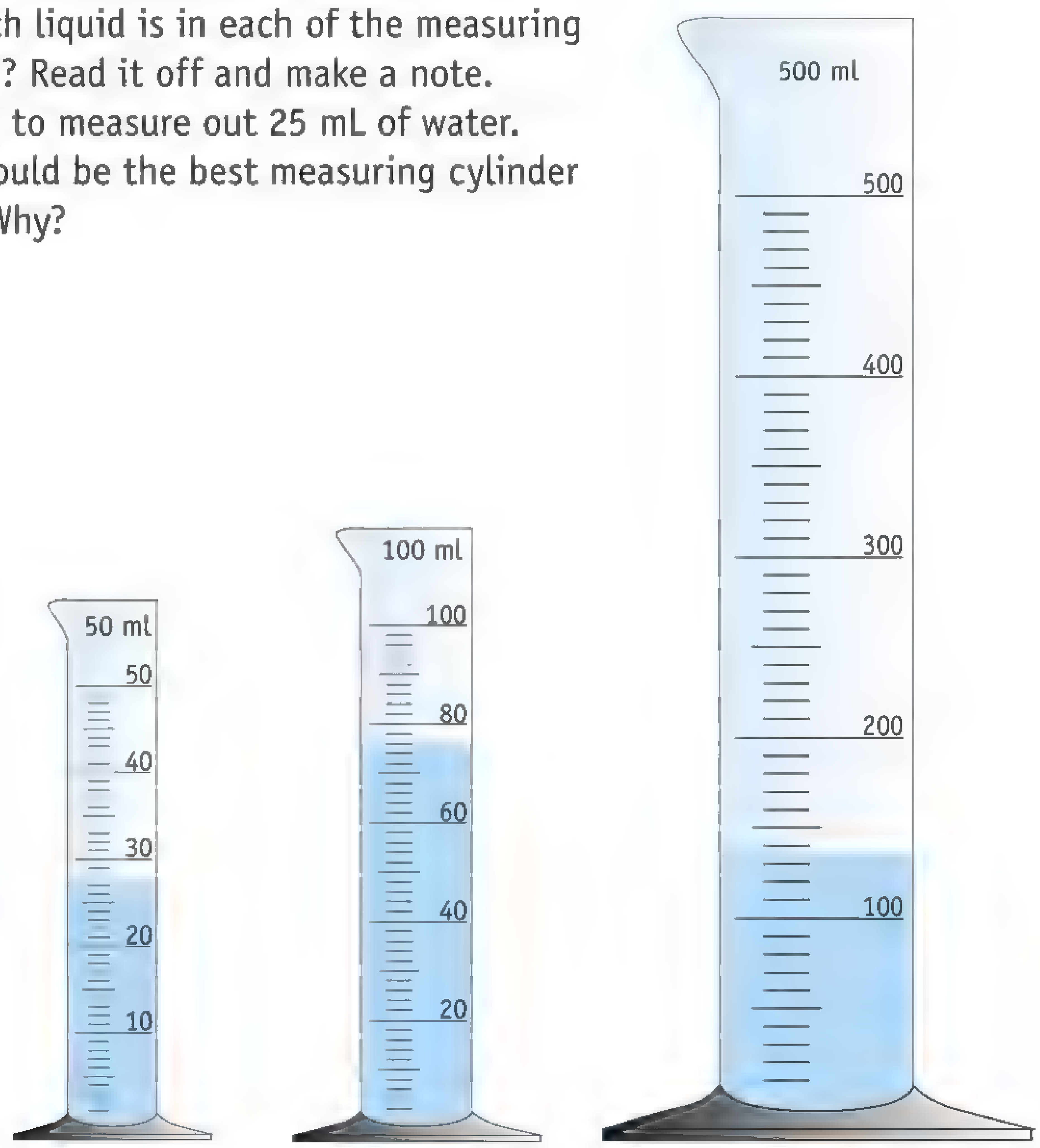
The contents of a	have a mass of
bag of sugar	1000 grams = ... kg
bag of macaroni	500 grams = ... kg
jar of peanut butter	400 grams = ... kg
pack of butter	250 grams = ... kg
packet of cocoa powder	100 grams = ... kg
cardboard shaker of pepper	50 grams = ... kg

24 See 'Skills 4' at the back of the book.
Copy and complete:

a	250 g = ... kg	**f**	1.3 kg = ... g
b	0.625 kg = ... g	**g**	0.25 t = ... kg
c	0.5 g = ... mg	**h**	0.75 kg = ... g
d	350 mg = ... g	**i**	810 g = ... kg
e	0.035 g = ... mg	**j**	8 mg = ... g

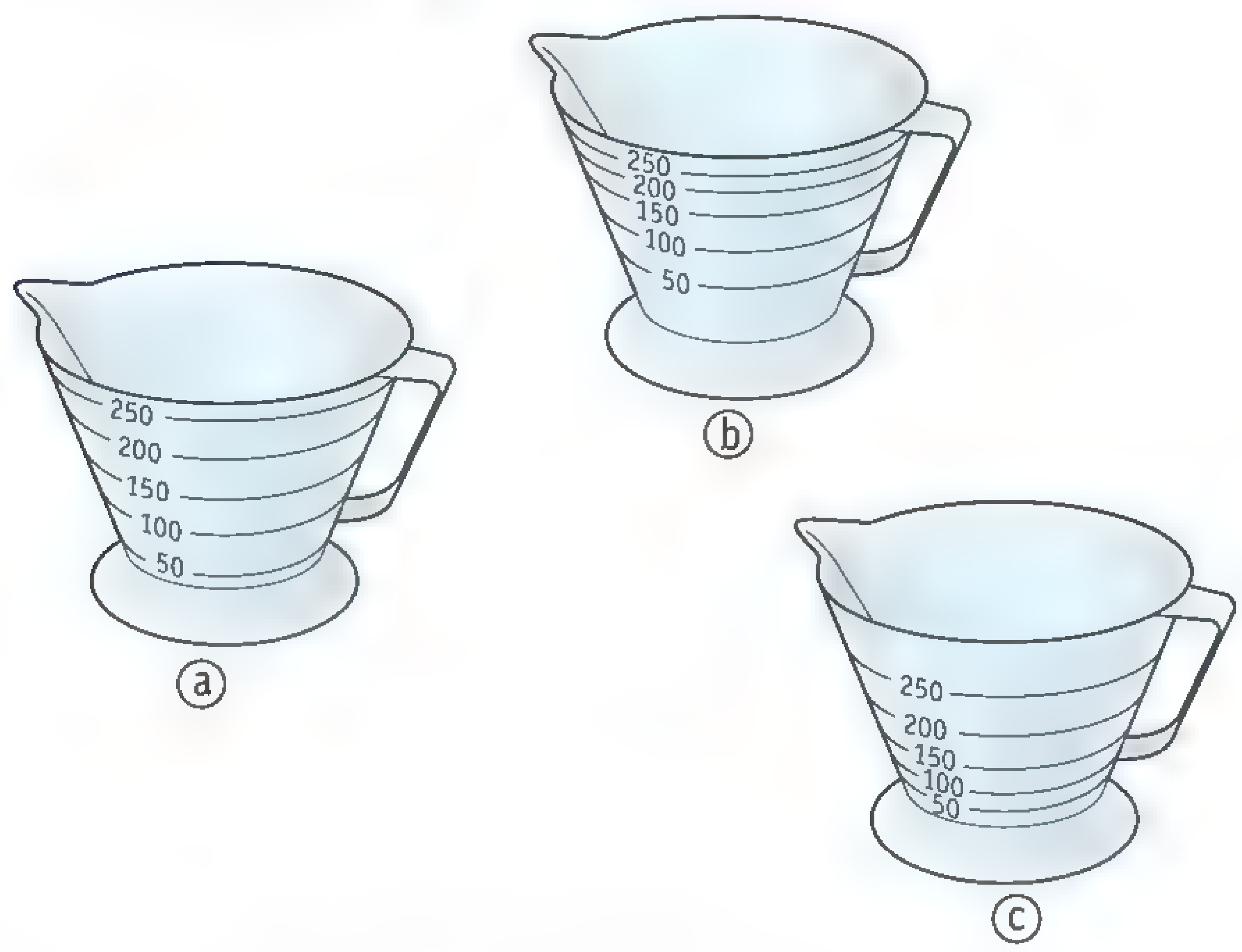
If you need more practice, go to the V-trainer.

25 Three measuring cylinders are shown in figure 21.
a How much liquid is in each of the measuring cylinders? Read it off and make a note.
b You have to measure out 25 mL of water. Which would be the best measuring cylinder to use? Why?



▶ **figure 21**
Read off the three measuring cylinders.

26 Around the home, measuring jugs may be used that look like the measuring jugs in figure 22.
In which of the drawings is the graduated scale on the measuring jug drawn correctly? Explain your choice.



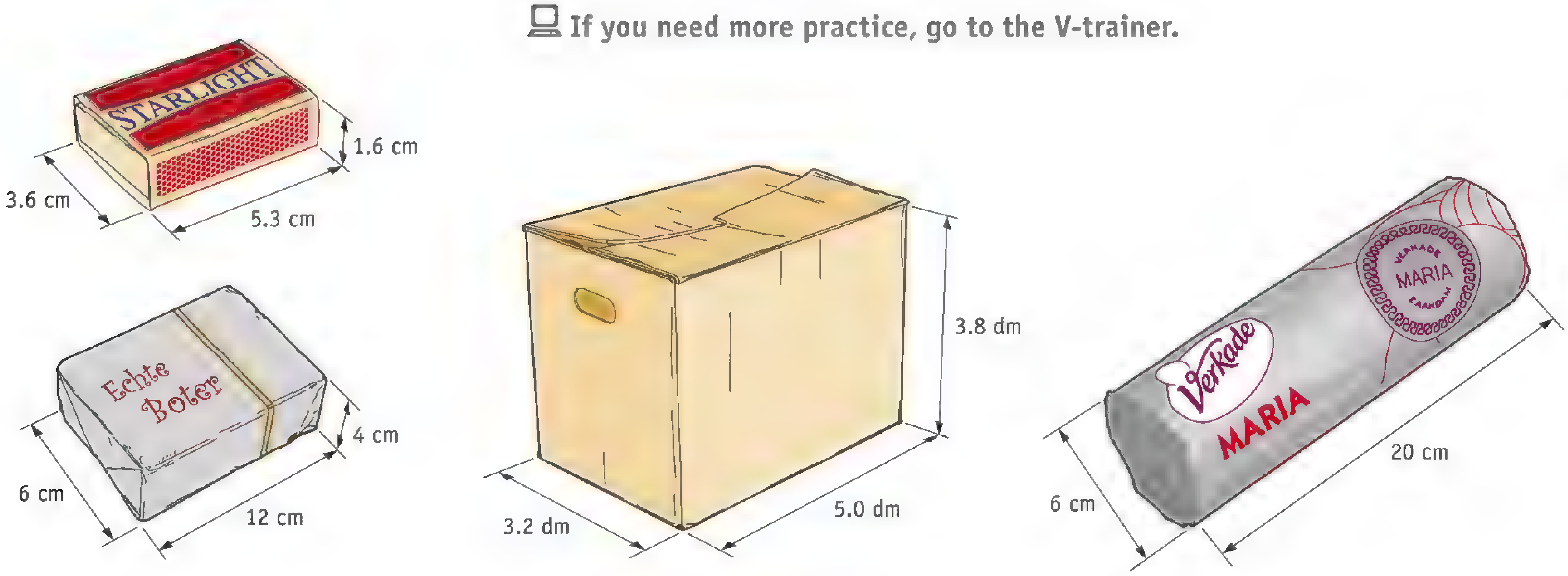
▶ figure 22
What does the graduated scale on a measuring jug look like?

27 Calculate the volumes of the objects shown in figure 23. Round the answers off to whole numbers. Always show all your calculation steps.

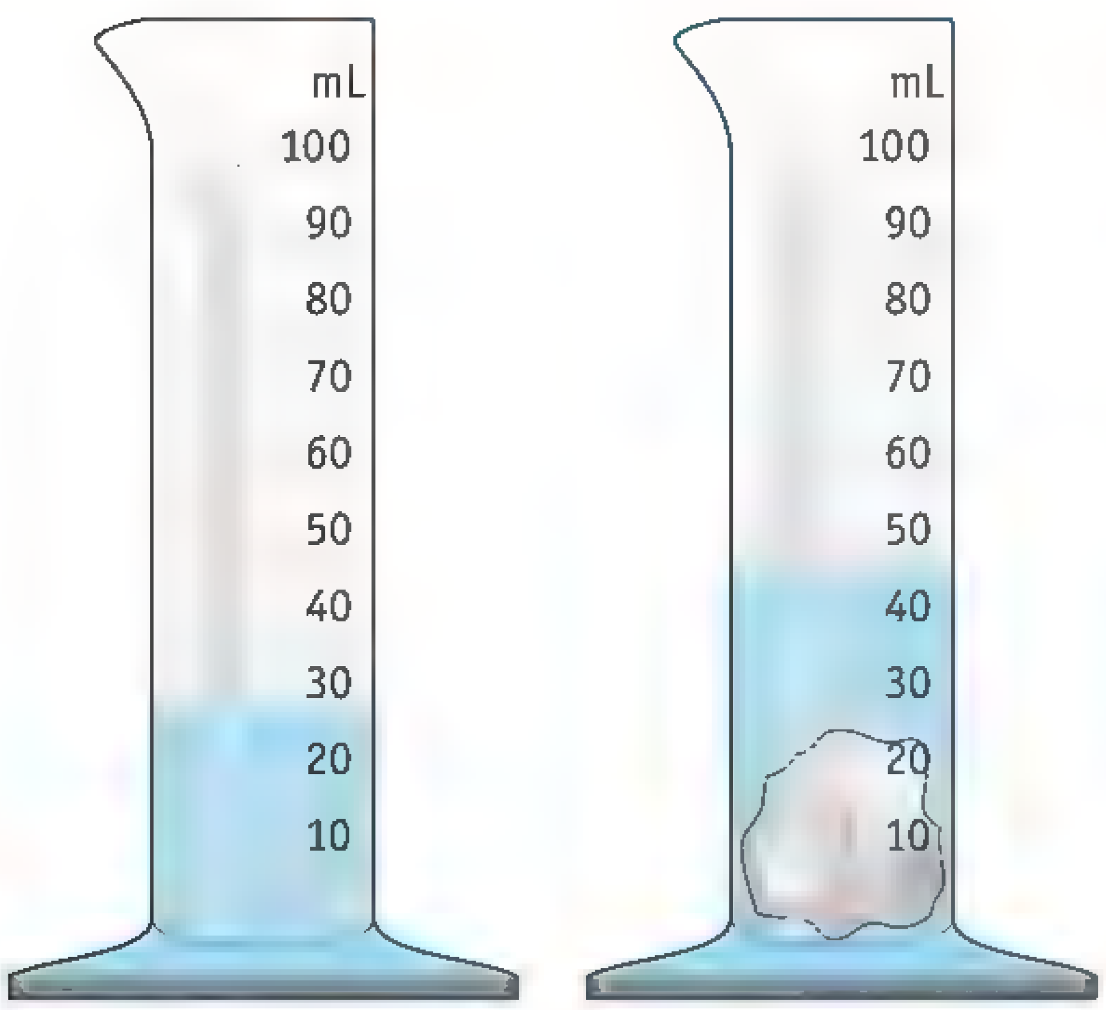
28 Copy and complete:

a	0.05 L	= ...... mL	**f**	0.625 m^3	= ...... dm^3
b	250 mL	= L	**g**	440 cm^3	= ...... dm^3
c	750 cm^3	= ...... dm^3	**h**	6.5 dm^3	= L
d	0.8 dm^3	= ...... cm^3	**i**	35 mL	= L
e	10 mL	= ...... cm^3	**j**	0.5 m^3	= L

If you need more practice, go to the V-trainer.



▲ figure 23
What is the volume of each of these objects?



▲ figure 24
What is the volume of the pebble?

29 Use the drawings in figure 24 to determine the volume of the pebble. Show all your calculation steps.

30 You could also use the immersion method in reverse: start by determining the final level, then remove the object and determine the starting level. Explain why this is not a good method.

31 Wood floats on water. How could you still use the immersion method to determine the volume of a block of wood? Write down two different ways.

32 A particular painkiller contains 200 mg of its active ingredient per tablet. The information leaflet says that you may not take more than 1.5 g of the active substance per day.
Calculate how many tablets you may take per day.

***33** The headline above a weather report said: "80 millimetres of rain in two days!"
Calculate how many litres of water fell on a garden of 6 m by 20 m in that period. Show all your calculation steps.

Plus The composition of mixtures

34 Vinegar is a solution of acetic acid in water. The Dutch Commodities Act states that a liquid may only be sold as vinegar if it contains at least 4 g of acetic acid per 100 mL of liquid.
- **a** What is therefore the minimum acetic acid concentration (in g/L)?
- **b** A recipe for mayonnaise says that you must add two tablespoons of vinegar. The volume of a tablespoon is 15 mL.
  Calculate how many milligrams of acetic acid there must be as a minimum in two tablespoonfuls.

35 A shot glass of spirits contains the same amount of alcohol as a glass of beer. The volume of the beer glass is 250 mL. The spirits are 35% alcohol by volume and the beer is 5%.
Calculate the volume of the shot glass.

Nova © Uitgeverij Malmberg

4 Density

People often say that one substance is heavier or lighter than another. If someone asks, "Why are alloy wheels often made of aluminium?" the reply is something like: "Because aluminium is a very light metal" or "Because aluminium is much lighter than steel".

▲ figure 25
three 1 cm³ blocks of: Perspex (1.2 grams), aluminium (2.7 grams) and brass (8.5 grams)

Light and heavy substances

How can you demonstrate that aluminium is lighter than steel? To do that, you have to be able to compare two substances 'fairly'. You can't just weigh an aluminium object and a steel object: an aluminium cycle frame could easily be heavier than the steel handlebars.

A fair way of comparing them is as follows:
1 Take a 1 cm³ block of each substance.
2 Determine the mass of each block using scales.
3 The block with the least mass is made of the 'lighter' substance.

An aluminium block of 1 cm³ has a mass of 2.7 grams. A steel block of 1 cm³ has a mass of 7.9 grams. Aluminium is therefore about three times lighter than steel.

The density of a substance

A 1 cm³ block of aluminium always has a mass of 2.7 g. That is one of the properties of the substance aluminium: there is always a mass of 2.7 g in a volume of 1 cm³. This property is so important that there is a special word for it, the **density**. You say that the density of aluminium is 2.7 grams per cubic centimetre (g/cm³).

▶ figure 26
Ladders are often made of aluminium.

Density is a property of a substance: every substance has its own specific density. Conversely, if you know the density of a substance, that helps you find out what substance it is (and which substances it definitely is not). The density is one of the properties that you can use to identify a substance.

You can find the densities of a number of substances in table 2. You can see for instance that metals can have very different densities. Aluminium is a lightweight metal with a density of 2.7 g/cm³. Gold is more than seven times heavier, with a density of 19.3 g/cm³. It is therefore very easy to tell gold and aluminium apart by their densities.

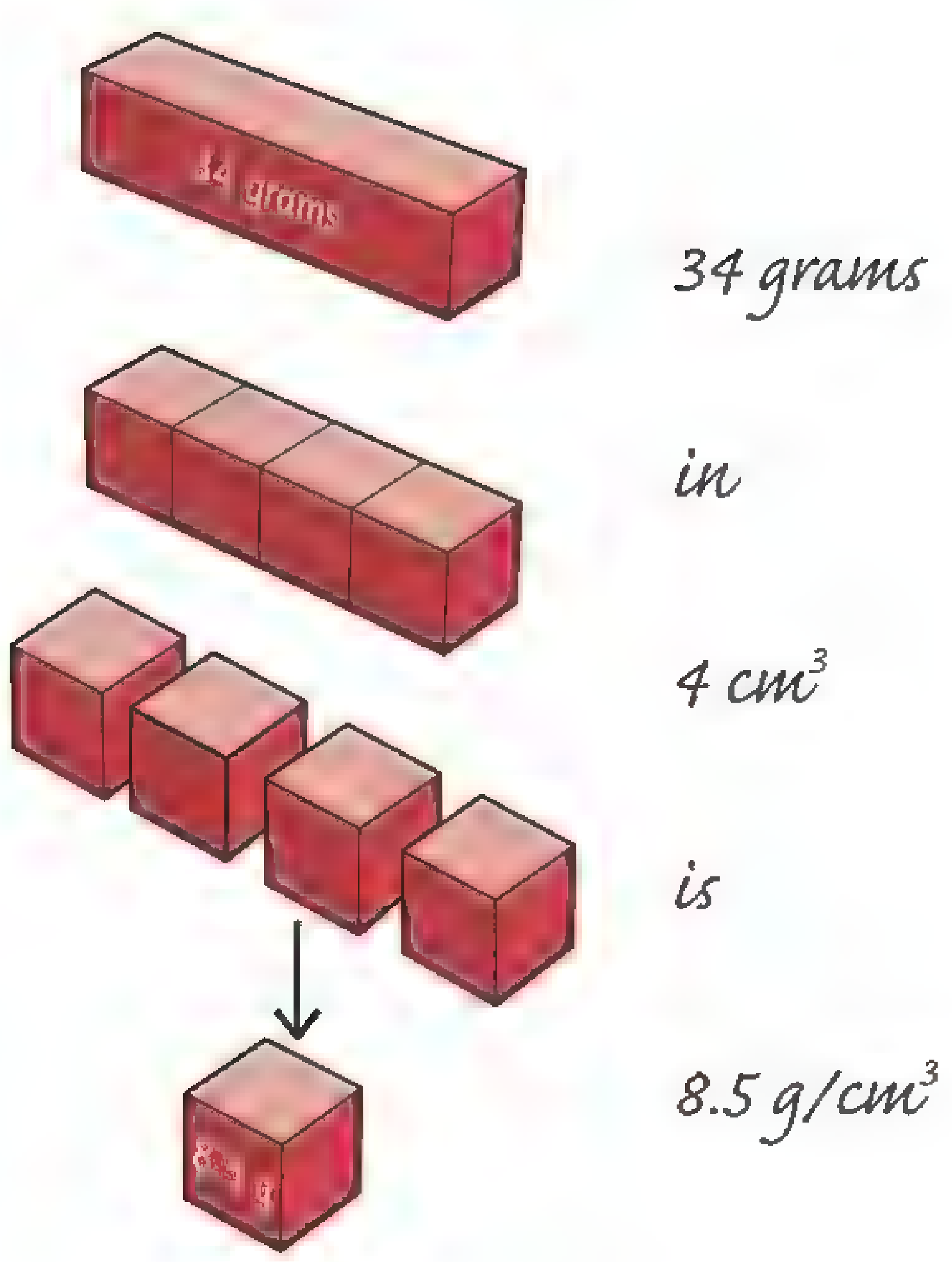
▼ **table 2** densities of a number of substances

substance	density (g/cm³)	substance	density (g/cm³)
alcohol	0.80	Perspex	1.2
aluminium	2.7	petrol	0.72
brass	8.5	pine	0.58
copper	8.96	silver	10.5
glass	2.6	steel	7.8
gold	19.3	sugar	1.6
ice	0.92	table salt	2.2
iron	7.9	turpentine	0.84
lead	11.3	water	1.0
mercury	13.5	zinc	7.2

Determining density Experiments 7 and 8

To determine the density you do not necessarily need an object with a volume of 1 cm³. It works just as well with a bigger object. You can mentally subdivide the object into blocks of 1 cm³. The question is then what the mass would be of a single block of 1 cm³.

Figure 27 shows a block of brass weighing 34 g. In your mind, you can split this block into four smaller blocks of 1 cm³. If you split the 34 grams over four blocks, each block will have 34 : 4 = 8.5 g. The density of brass is therefore 8.5 g/cm³.



◀ **figure 27**
This is how you can calculate density.

This is a method that always works: divide the mass (in g) by the volume (in cm^3) and you will get the density in g/cm^3. You can also write that as a formula:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

or in symbols:

$$\rho = \frac{m}{V}$$

The symbol for density is the Greek letter ρ (rho, pronounced to rhyme with 'go').

Worked example 2
Miranda has a gold-coloured bracelet with a mass of 78 g and a volume of 5.0 cm^3 (figure 28).
Calculate whether this bracelet might be made of pure gold.

data $m = 78$ g
$V = 5.0$ cm^3

required $\rho = ?$

working $\rho = \dfrac{m}{V} = \dfrac{78}{5.0} = 15.6\ g/cm^3$

The bracelet can therefore not be made of pure gold, because that has a density of 19.3 g/cm^3 (see table 2). However, the bracelet could be mostly made of gold.

◀ figure 28
A lovely bracelet… but is it really made of gold?

Plus Floating and sinking

Olive oil and water do not mix well. If you put olive oil and water together and shake thoroughly, you do get a mixture for a while. However, the two liquids separate out again quickly. The mixture separates out into a layer of olive oil and a layer of water: the olive oil is on top and the water is underneath.

In this type of experiment, the liquid with the lower density will always end up on top. Because this liquid is lighter, it floats on the other liquid. The density of olive oil is 0.92 g/cm³; the density of water is 1.0 g/cm³. That is why olive oil floats on water, and not the other way around.

In just the same way, you can predict whether a solid object (one without any hollows or cavities) will float or sink. An object made of pine floats in water because pine wood (ρ = 0.58 g/cm³) has a lower density than water (ρ = 1.0 g/cm³). However, an object made of Perspex (ρ = 1.2 g/cm³) will sink in water.

Exercises

36 See 'Skills 2' at the back of the book.
Copy table 3 and fill in the missing words and symbols.

▼ **table 3** variables and units

variable	symbol	unit	symbol
length		metres	
	m		kg
		litres	
		grams per cubic centimetre	

37 Suppose: your teacher gives you the task of determining the density of brass. You are given a rectangular block of brass to work with.

a What two variables will you measure first?
b What measuring instruments do you need for this?
c What formula will you then use to calculate the density?
d Finally, what unit will you put after the result?

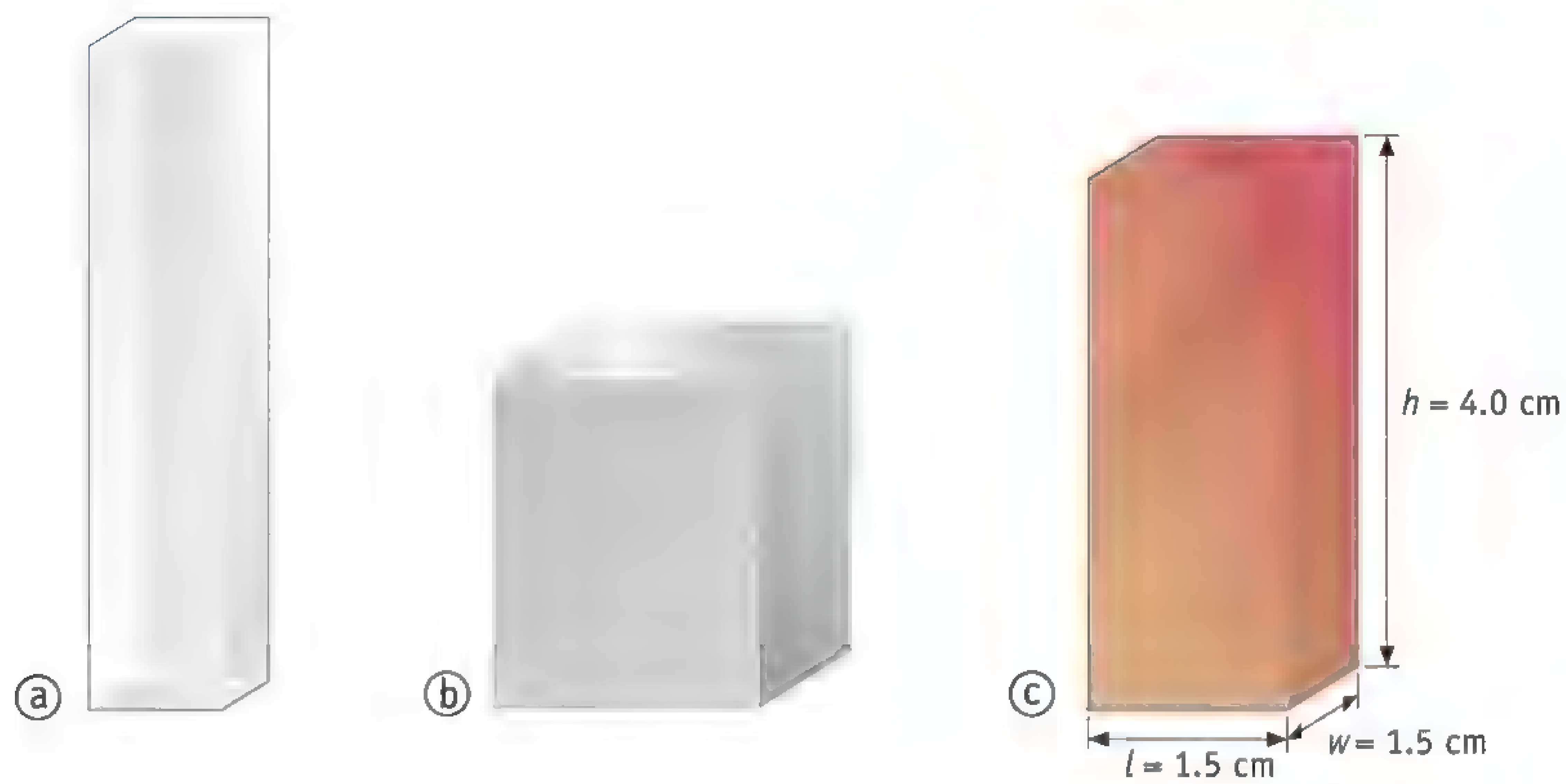
38 Put the metals in table 2 in sequence according to their density.
Which of the metals on this list has:

a the highest density?
b the lowest density?
c the middle density value?

39 Figure 29 shows three blocks that are each made of a pure substance.

a Calculate the density of the substances that each of these objects are made of, to one decimal place. Show all your calculations.

b For each of these objects, state what substance it might be made of. Use table 2.



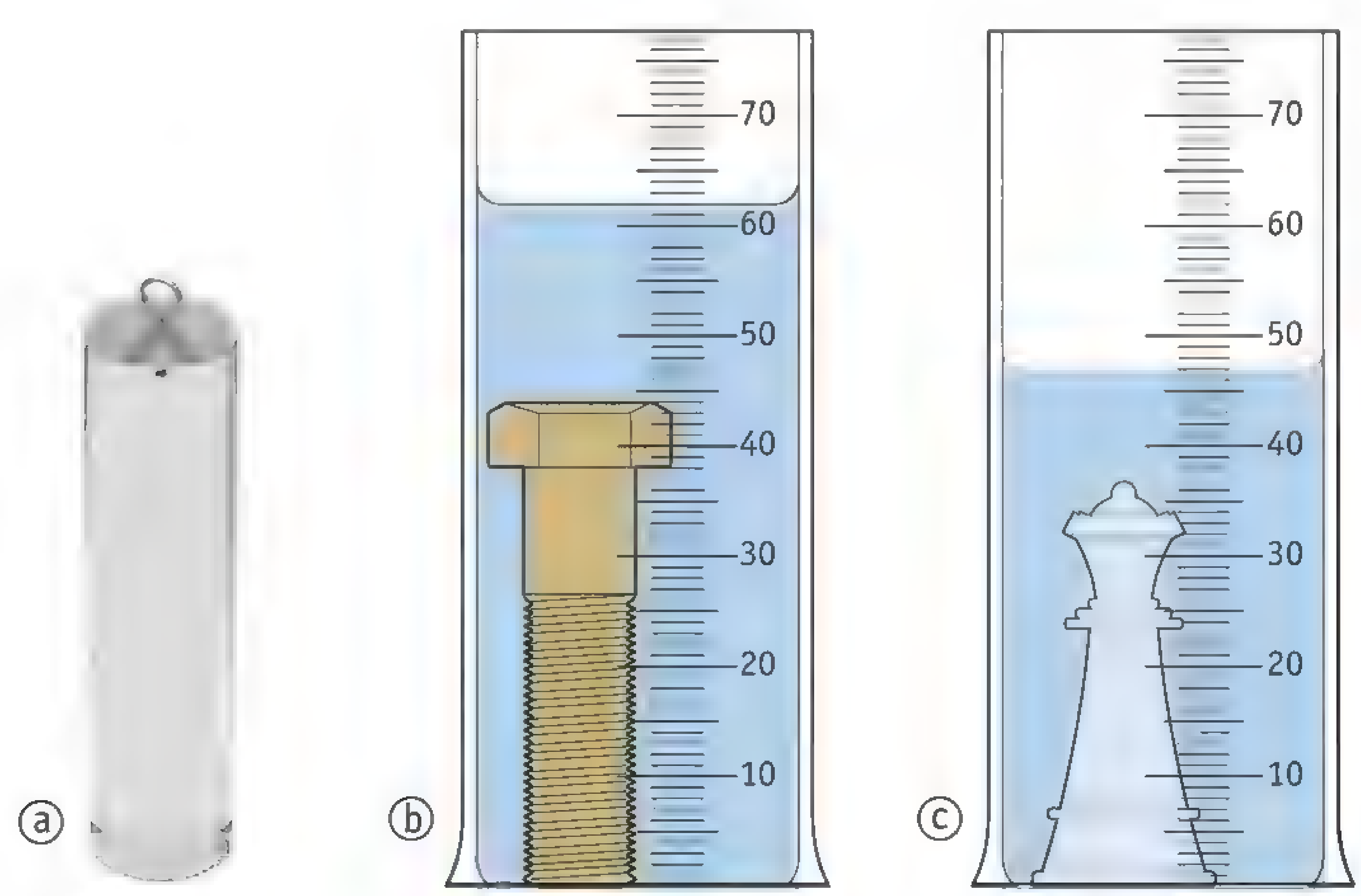
▶ **figure 29**
three rectangular objects

a	b	c
mass = 6.0 g	mass = 27 g	mass = 80 g
volume = 5.0 cm^3	volume = 10 cm^3	volume = ...

40 Three more objects are shown in figure 30.

a Calculate the density of the substances that each of these objects are made of, to one decimal place. Show all your calculation steps.

b For each of these objects, state what substance it might be made of. Use table 2.



▶ **figure 30**
a cylinder and two irregularly shaped objects

a	b	c
mass = 26 g	mass = 68 g	mass = 63 g
volume = 10 cm^3	initial reading = 54 cm^3	initial reading = 41 cm^3

▼ **table 4** mass and volume

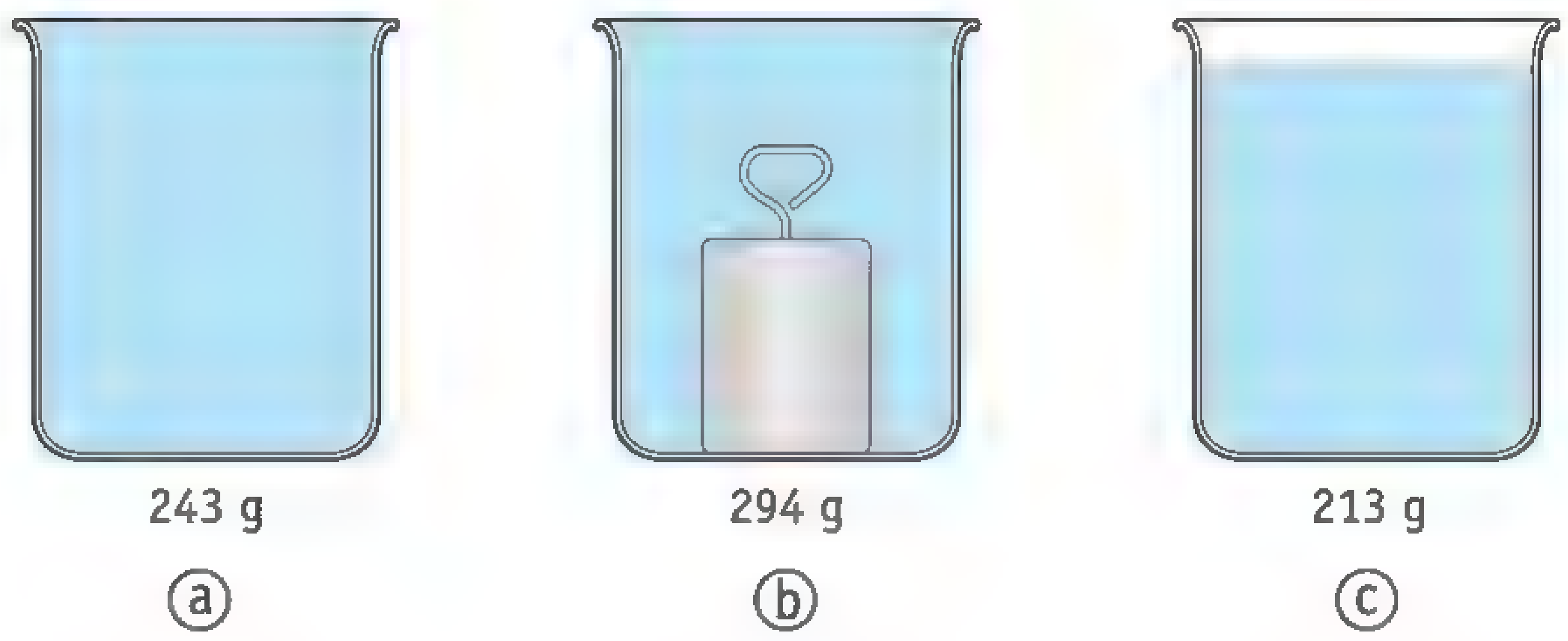
volume (cm^3)	mass (g)
9.5	75.0
6.8	48.3
7.2	56.8
4.5	35.5

41 Mitchell has measured the mass and the volume of four objects. His measurement results are shown in table 4.
- **a** Which three objects could be made of the same material?
- **b** Calculate the density of this substance.
- **c** What substance might it be?

42 On a shelf in the supermarket, there are large and small bottles of orange juice.
- On the big bottles, it says: 1000 g | 930 mL
- On the small bottles, it says: 500 g | 465 mL
- **a** Explain how these numbers show you that both types of bottle are filled with the same liquid.
- **b** Work out what volume the manufacturer would have to put on a bottle containing 200 g.

***43** A kitchen measuring beaker has graduations in grams for flour and sugar. This lets you measure out quantities of these ingredients without needing scales.
The mark for 300 g of flour is lower than the mark for 300 g of sugar.
Explain which of the two ingredients has the lower density (on average).

***44** A glass beaker filled to the top with water has a mass of 243 g (figure 31a). Tommy lowers a metal block into it on a thin wire (figure 31b) and then measures the mass of the beaker again: 294 g. Finally, he lifts the block out again and measures the mass of the beaker again with the remaining water: 213 g (figure 31c).
Use this data to calculate the density of the metal. Round the value off to one decimal place.



▶ **figure 31** What is the density of the metal?

Plus Floating and sinking

45 Use table 2 to help predict:
- **a** whether petrol will float on water or sink to the bottom.
- **b** whether an ice cube will sink or float in alcohol.
- **c** whether a steel nail will sink or float in mercury.

▶ figure 32
Floating in the Dead Sea.

46 The water of the Dead Sea is very salty. As a result, you can stay afloat very easily in the water (figure 32).
What does this tell you about the density of salt water compared to fresh water?

47 A layered cocktail consists of different drinks that are poured carefully, one on top of the other (figure 33).

a What order do the drinks have to be poured into the glass in?
b Why does each drink have to be poured in extremely carefully?
c The drinks consist mostly of water, alcohol and sugar.
Where will you find a drink containing not much sugar and a lot of alcohol?
A At the top of the glass.
B At the bottom of the glass.
C Impossible to say.
d Explain how you arrived at your answer to c.

▶ figure 33
a layered cocktail

Nova © Uitgeverij Malmberg

Experiments

Experiment 1 Distinguishing between substances 30 min

Introduction

When the police raid a drugs laboratory, they often find all sorts of substances there. To determine what the substances are, the police have a special investigations department.
You will be doing something very similar in this experiment, but using harmless substances. You will be given sixteen jars containing substances, without knowing what any of them are. You must use the substance properties to identify as many of the substances as possible.

Aim

This experiment teaches you to identify substances using their properties.

Requirements

- sixteen substances in bottles

Doing the experiment and writing it up

– You are given sixteen bottles. You may open the bottles to smell them. You must definitely not taste the substances!

1 Copy table 5 into your exercise book and complete it. Make a note of:
  - **a** the colour of the substance;
  - **b** the odour of the substance;
  - **c** whether the substance is solid, liquid or gaseous;
  - **d** other details;
  - **e** the name of the substance (if you know it).

2 Have a look at the data in the table.
  - **a** Which substances are solid?
  - **b** Which substances are liquid?
  - **c** Which substances are gaseous?
  - **d** Which substances are metals?
  - **e** Which substances are transparent?

▼ table 5 sixteen substances and their properties

number	colour	odour	solid/ liquid/ gas	details	name
1					
2					
3					
etc.					

Experiment 2 Investigating suspensions and solutions 15 min

Introduction
You come across various sorts of mixtures in daily life. Tea (without milk) and cola are examples of solutions. Orange juice and paint are examples of suspensions.

Aim
In this experiment, you will learn to recognize two differences between solutions and suspensions.

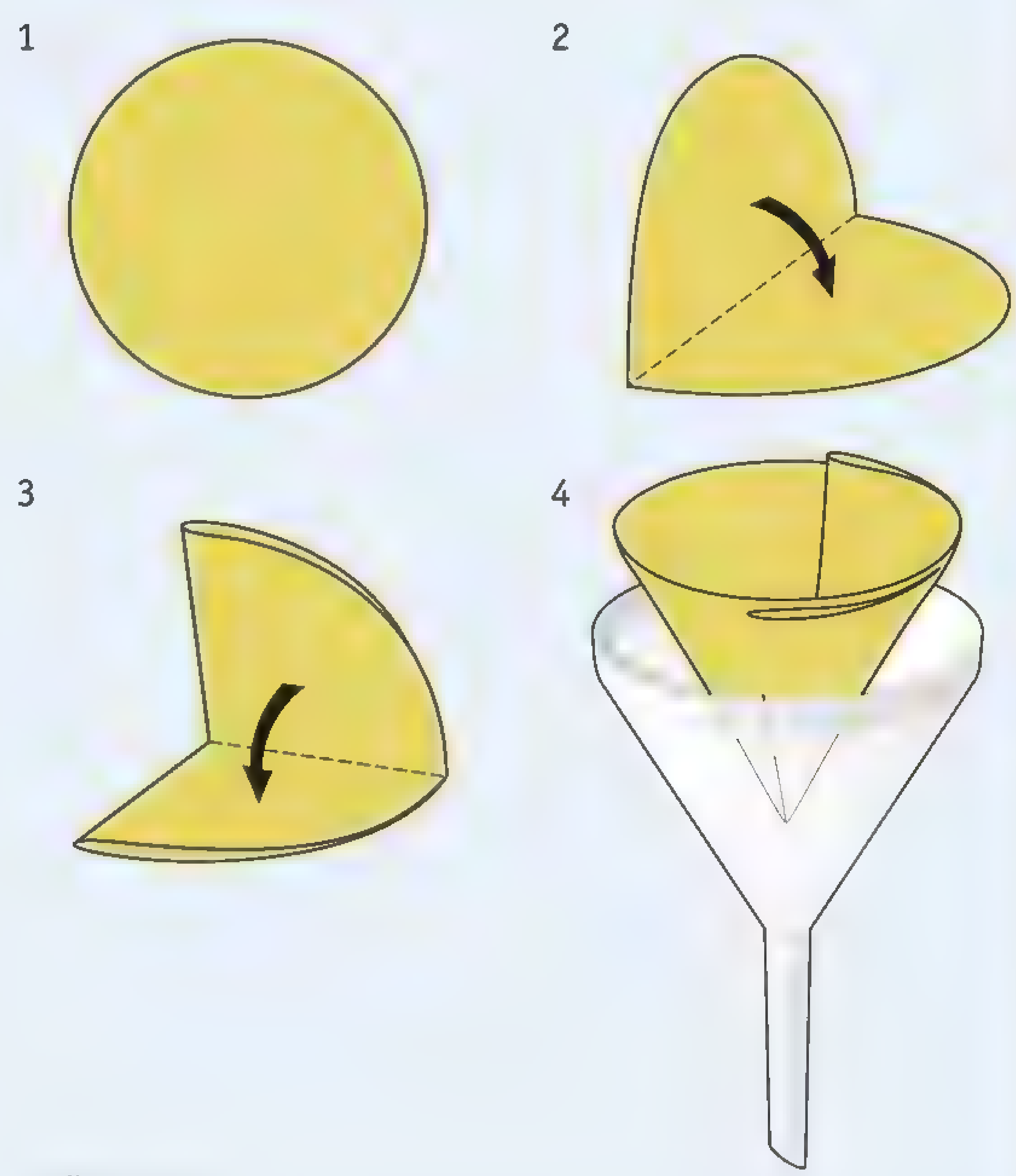
Requirements
- test tube with water + ink
- test tube with water + charcoal
- two (empty) test tubes
- two funnels
- two filter papers

Doing the experiment and writing it up
- Shake the test tube with water + ink. Look immediately afterwards to see if you can see through the mixture.
- Shake the test tube with water + charcoal. Look immediately afterwards to see if you can see through the mixture.

1 Can you see through the diluted blue ink?
2 Is this a solution or a suspension?
3 Can you see through the mixture of charcoal and water?
4 Is this a solution or a suspension?

- Fold the filter papers as shown in figure 34 and put them in the funnels.
- Moisten the filters with water; they will then stay in place in the funnels better.
- Put the funnels in the empty test tubes.
- Shake the mixture of water + ink and pour it carefully into one filter.
- Shake the mixture of water + charcoal and pour it carefully into the other filter.
- Watch carefully to see what happens.
- Wait until nothing more is dripping out of the filters.

5 What do the liquids in the tubes underneath look like?
6 In which of the filters did a solid residue remain behind?
7 What substance or substances are in the residue?
8 What substance or substances definitely went through the filter in the water + ink mixture?
9 What substance or substances definitely went through the filter in the water + charcoal mixture?



▲ figure 34
How to fold a filter.

Experiment 3 Working with a Bunsen burner 30 min

Introduction
In your experiments at school, you will often be using a Bunsen burner to heat things. You always have to be careful when you use a gas burner.

Stick to the safety instructions that your teacher has discussed with you.

Aim
In this experiment you will learn about the properties of a gas flame and how to work with a Bunsen burner. See 'Skills 6' at the back of the book.

Requirements
- gas burner (Bunsen burner)
- wire mesh
- wooden test tube rack
- matches/lighter
- worksheet 2-1

Doing the experiment and writing it up
- Check that the gas control knob and the air flow control knob on the burner are closed (figure 35).
- Open the gas tap on your bench.
- Hold a burning match above the Bunsen burner and open the gas control knob a little.

1 What colour is the flame of the burner?

- Open the air control knob a little more.

2 What happens to the colour of the flame?

- Open the air flow control knob a good bit wider.

3 What happens to the colour of the flame?
4 What can you hear?

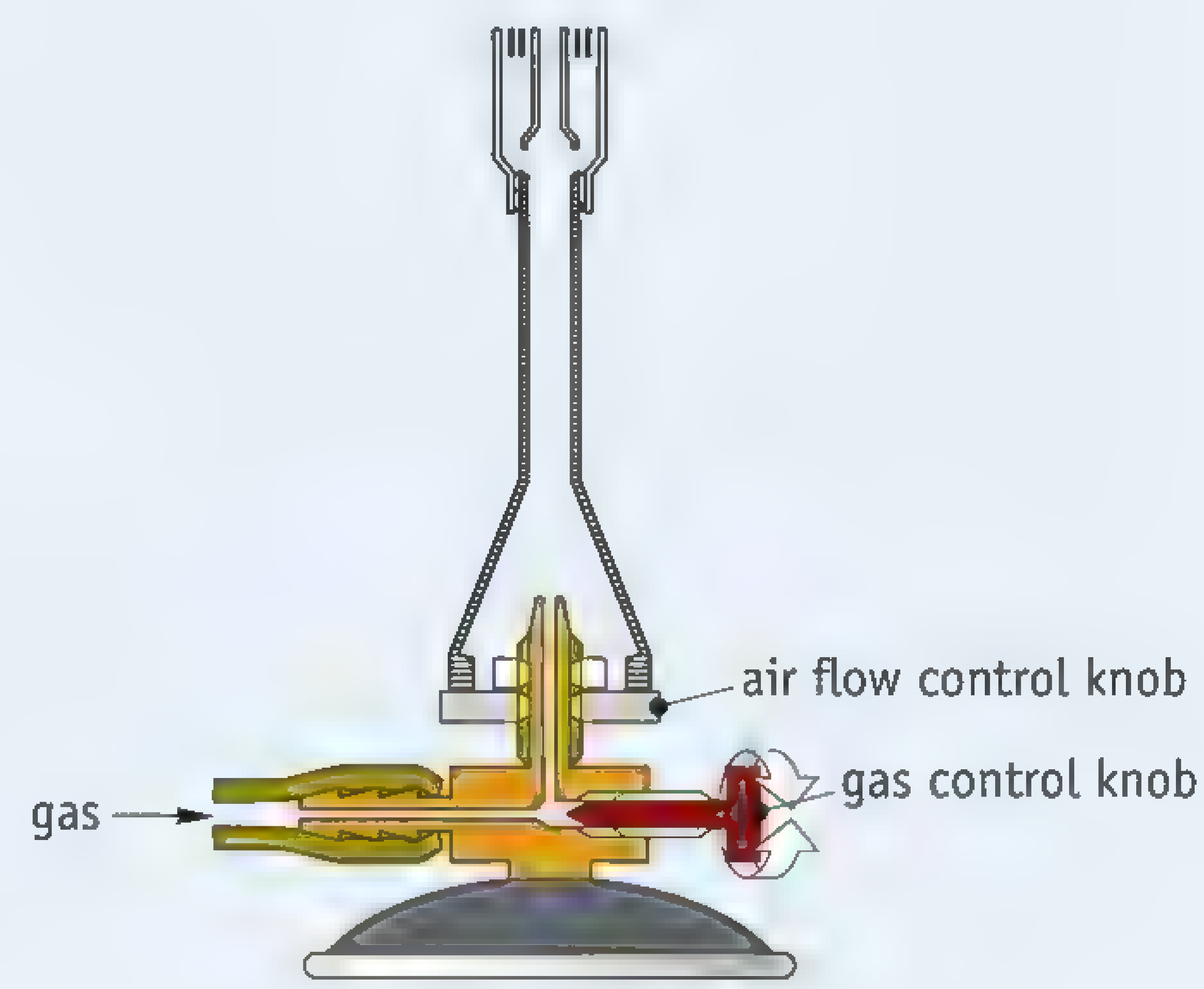
- Hold the wire mesh vertically in the flame (see drawing a in the worksheet).

5 Draw and colour in what you see on the worksheet.

- Hold the wire mesh horizontally in the flame (see drawing b in the work sheet):
  a first for thirty seconds in the blue heart of the flame;
  b then for thirty seconds just above the blue heart of the flame;
  c finally for thirty seconds at the top of the flame.

6 Draw and colour in what you see on the worksheet.
7 Where is the flame hottest? How can you see that?

- Close the air flow control knob.
- Close the gas control knob.
- Close the gas tap on your bench.



▲ figure 35
a Bunsen burner

Experiment 4 Extracting rock salt 30 min

Introduction
Rock salt is extracted (mined) by pumping hot water into the ground. Deep underground a mixture of water and rock salt is created, known as brine. The brine is then pumped up, after which the salt is extracted from the brine.

Aim
In this experiment you are going to heat brine until rock salt is left over.

Requirements
- rock salt
- distilled water
- glass beaker
- stirring rod
- test tube
- funnel
- filter paper
- small porcelain/steel crucible
- Bunsen burner
- tripod
- wire mesh
- matches/lighter

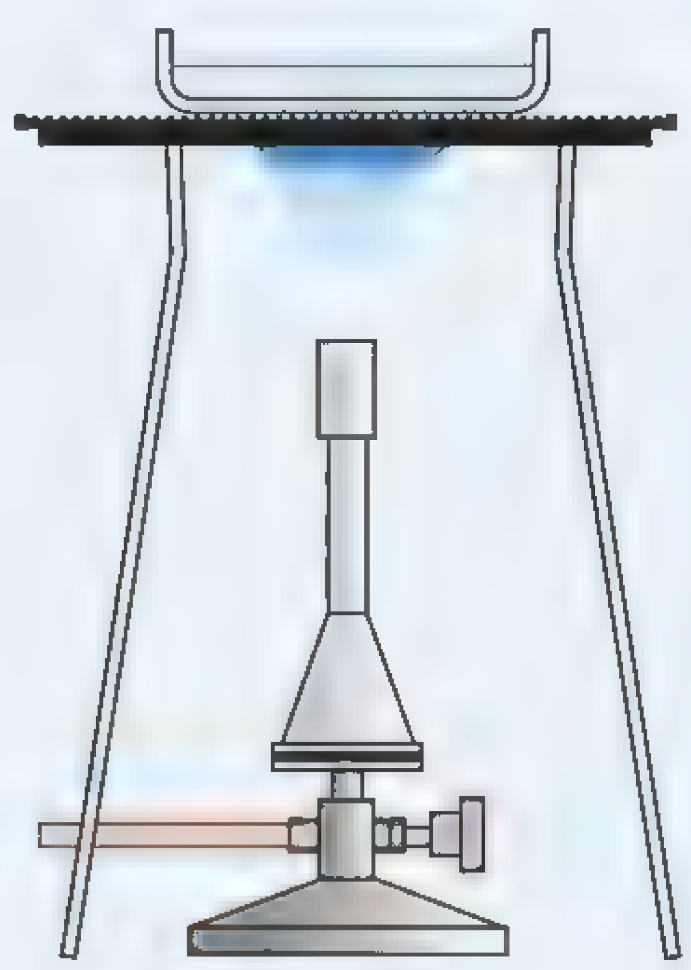
Doing the experiment and writing it up

Dissolving and filtering
- Put a couple of spoonfuls of rock salt in the beaker.
- Add a little hot water to the rock salt and stir it thoroughly.
- Filter the liquid and collect the filtrate in a test tube.

Evaporation
- Put the gauze (the wire mesh) on the tripod. Put the crucible on the wire mesh.
- Pour a little bit of the liquid from the test tube into the crucible.
- Set the Bunsen burner to a small, colourless flame (figure 36).
- Heat the liquid in the crucible until all the water has evaporated.

Note: take the burner out from under the gauze if the liquid starts to spit too much. Make the flame smaller by closing the gas control knob a bit. Then put the burner back under the gauze.

1 Is there any solid material left behind in the filter after filtration?
2 Describe the contents of the crucible after evaporation.
3 What can you say about the solubility of this substance?



▲ figure 36
the setup for experiment 4

Experiment 5 Determining volume and mass 30 min

Introduction
You can look at either the mass or the volume when you want to determine the quantity of a substance. In the supermarket, for instance, you will find one-litre packs of milk as well as one-kilogram packs of sugar. Units of volume and mass are also often used side by side in recipes. You may, for example, see: "Add 250 g mushrooms and 100 mL water."

Aim
In this experiment, you are going to determine the volumes and masses of four rectangular objects.

Requirements
- four different blocks
- ruler or drafting protractor
- scales

Doing the experiment and writing it up
1 Copy table 6 into your exercise book.
Write down what each block is made of in column 1.

– Measure how long the sides of the blocks are (in cm).

2 Write down the measurements in the table.

3 Calculate the volume of each block using the formula $V = l \cdot w \cdot h$.
Round the answer to a whole number and note it down in column 2.

– Determine the mass of each block using the scales.

4 Make a note of the mass of each block in the final column of the table.

▼ table 6 the measurement results for experiment 5

object	length (cm)	width (cm)	height (cm)	volume (cm^3)	mass (g)
1					
2					
3					
4					

Experiment 6 Working with the immersion method 15 min

Introduction
There is no simple way of calculating the volume of an irregularly shaped object using a formula. For objects like that, you have to use the immersion method.

Aim
In this experiment you will learn how to determine the volume of two objects using the immersion method.

Requirements
- measuring cylinder
- aluminium block
- pebble

Doing the experiment and writing it up
– Fill the measuring cylinder about two thirds full with water. Read the level of the water (in cm^3). See 'Skills 5' at the back of the book.

1 Copy and complete:
The starting level is ...... cm^3.

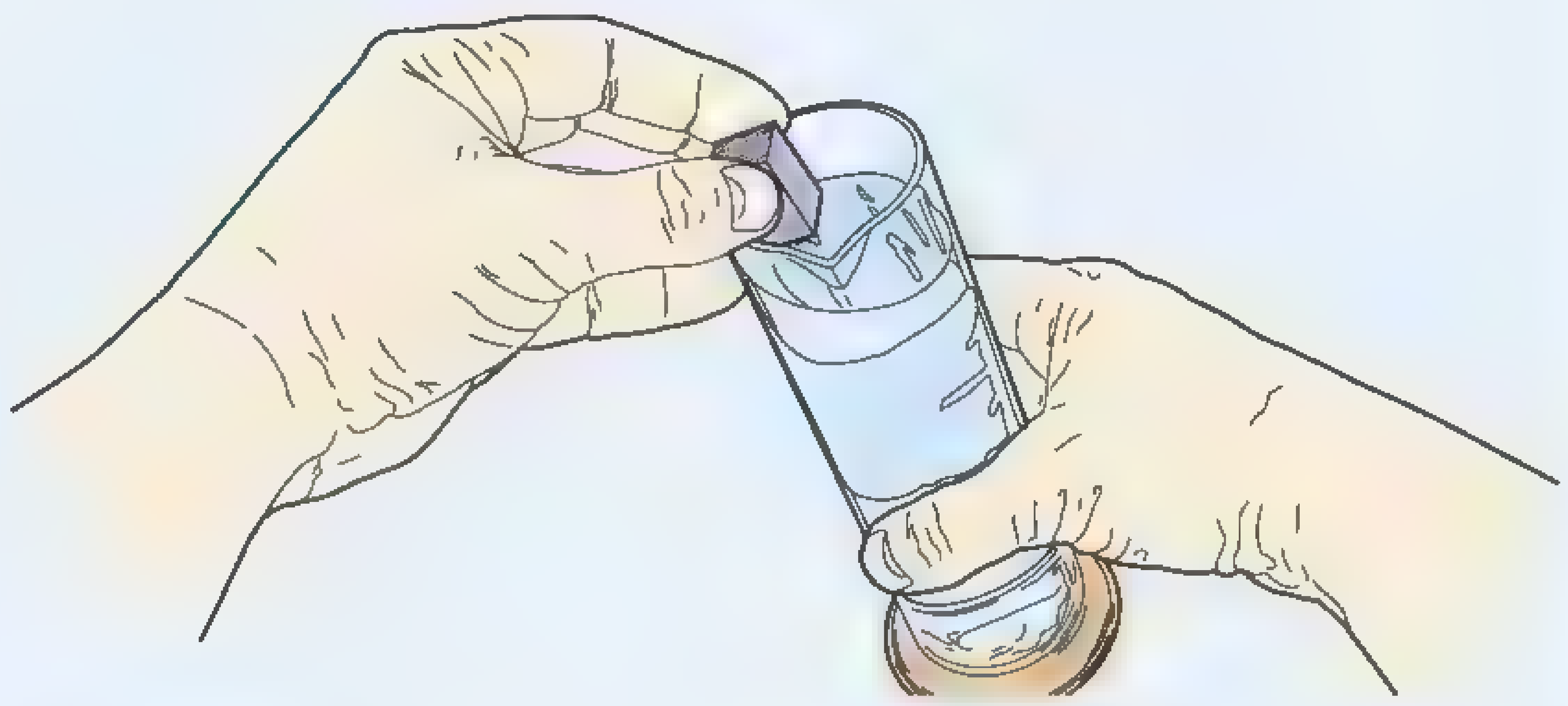
- Carefully allow the aluminium block to sink beneath the surface of the water (figure 37).
- Read the level of the water again (in cm³).

2 Copy and complete:
The final level is ...... cm³.

3 What is the volume of the block?
Copy and complete:
volume of block = final level minus starting level = ... − ...... = ...

- You are now going to determine the volume of an irregularly shaped object. In this case it is a pebble.

4 Copy and complete:
volume of pebble = final level minus starting level = ... − ...... = ...



▲ **figure 37**
Keep the measuring cylinder tilted as you lower the block into it.

Experiment 7 Determining density 45 min

Introduction

Researchers can often say exactly what substance is present if they know the density. You can calculate the density by dividing the mass (in g) by the volume (in cm³). This gives you the density in g/cm³.

Aim

Determining the density lets you find out what substance an object is made of. You are going to do that in this experiment.

Requirements

- measuring cylinder
- ruler or drafting protractor
- scales
- five objects

Doing the experiment and writing it up

- Determine the densities of the substances that the five objects are made of.

1 Copy table 7 into your exercise book.
Write your measurement results down in the table.
2 Use the formula to calculate the density of each object.
Round off the results to one decimal place.
Note the results in the correct place in the table.

- Compare the densities that you have determined against the densities in table 2.

3 Write down in the table the substance that each of the objects is probably made of.

▼ **table 7** the measurement results for experiment 7

object	mass (g)	volume (cm³)	density (g/cm³)	substance
1				
2				
3				
4				
5				

Experiment 8 The density of a liquid 30 min

Introduction
You can determine the density of a liquid by dividing the mass of the liquid by its volume.

Aim
In this experiment, you will be determining the densities of two liquids.

Requirements
- scales
- measuring cylinder
- distilled water
- methylated spirits

Doing the experiment and writing it up
– Think how you can determine the mass and the volume of a quantity of a liquid.

1 Write down the measurements and calculations that you are going to do, and in what order.

– Determine the densities of water and methylated spirits to one decimal place.

2 Note down all the measurements, calculations and results in your exercise book.

Experiment 9 Carrying out research: salt in reclaimed land 45 min

Introduction
Imagine: a dyke has broken and a large area of farmland has been flooded. This means salt has ended up in the soil. That is a problem when growing crops, which means losses for the owner of the land. The land owner's insurance company asks for a report saying (among other things) how much salt ended up in the soil. A research laboratory is called in to investigate. In this experiment, you are the lab technician who has to carry out the research.

Aim
In this experiment, you will be determining the level of salt in a soil sample. The result has to be reported as grams of salt per kilogram of soil.

Requirements
For this experiment, you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up
– Think how you are going to be able to provide a reliable answer to the study question. What are you going to measure, what items will you need for the experiment, and how are you going to work out your answers afterwards?

1 Make a work plan for this research.
See 'Skills 1' at the back of the book.

– The work plans will be discussed with the rest of the class in the next lesson. If necessary, you can make improvements to your own work plan after that.
– Then carry out the experiment.

2 Note down all the measurements, calculations and results in your exercise book.

– Your teacher will tell you whether or not you have to write up a report on this experiment.

Nova © Uitgeverij Malmberg

Test Yourself

You can also do questions 1 to 16 on the computer.

1 A bottle contains a clear, colourless liquid with a strong smell.
Could it be:
a alcohol?
b methylated spirits?
c olive oil?
d sugar?
e white spirits?
f water?

2 Which of the following properties are not substance properties?
a colour
b flammability
c mass
d density
e price per kilogram

3 Figure 38 shows four hazard symbols.
Which hazard symbol can be used to show that a substance:
a is toxic?
b is corrosive?
c is oxidizing?
d can irritate the eyes and skin?

▲ figure 38
four hazard symbols

4 Say whether the following statements are true or false.
a A mixture contains different kinds of molecules.
b Solutions are clear and always stay perfectly mixed.
c You can extract dissolved substances from the solvent using a filter.
d A suspension is cloudy: you cannot see through it.
e Coffee and tea (without milk) and cola are examples of suspensions.
f Some solutions are colourless and others are coloured.

5 What is the residue when you make coffee in a percolator?
A The ground coffee that you spoon into the filter from the pack.
B The hot water that drips through the ground coffee.
C The freshly made coffee in the jug under the filter.
D The coffee grounds that remain in the filter afterwards.

6 You can get the aromas and flavourings out of parts of plants by putting them in a suitable solvent.
What is the name for this method of obtaining substances from plants?

7 On a medicine bottle, it says to shake well before use.
What sort of mixture will this medicine probably be?

8 Convert:

a	0.85 g = ... mg	**h**	175 mL = ... L
b	0.045 kg = ... g	**i**	0.234 m^3 = ... dm^3
c	304 g = ... kg	**j**	0.01 L = ... mL
d	0.750 t = ... kg	**k**	0.35 L = ... cm^3
e	625 mg = ... g	**l**	205 cm^3 = ... dm^3
f	980 kg = ... t	**m**	63 mL = ... cm^3
g	0.78 dm^3 = ... cm^3	**n**	400 dm^3 = ... m^3

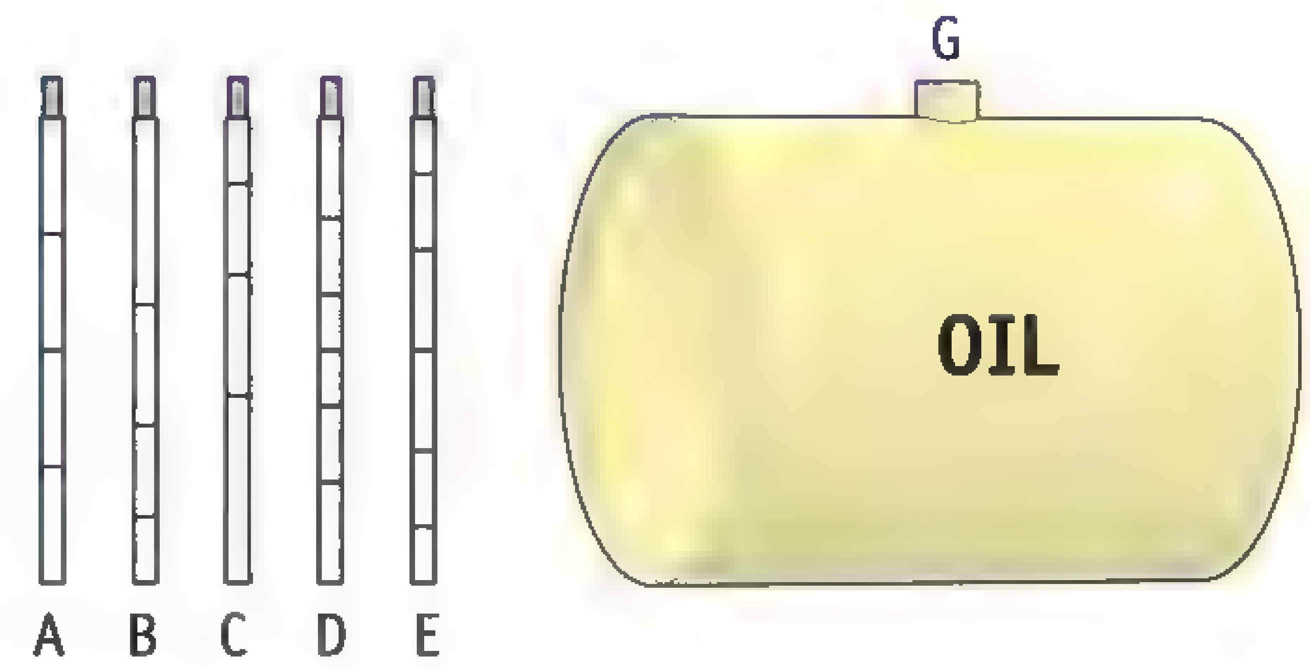
If you need more practice, go to the V-trainer.

9 The list of ingredients for a recipe states 'two tablespoons of sunflower oil'.
In this case, a 'tablespoon' is:
A A not very precise but convenient unit of mass.
B A not very precise but convenient unit of volume.
C A not very precise but convenient unit of density.
D Not a unit: you can also measure things out without using units.

10 In figure 39 you can see a number of small cylinders that are used at a school for density tests. The cylinders are 4.0 cm high and have a diameter of 1.0 cm.
Calculate the volume of one cylinder.

▲ figure 39
What is the volume of one cylinder?

11 An oil tank is shown in figure 40. To measure how much oil is still in the tank, a dipstick is used. It is inserted into the tank through hole G. A graduated scale has been marked on the dipstick, with each successive mark indicating the same change in volume.
Which dipstick shows the correct graduations for this tank: A, B, C, D or E?

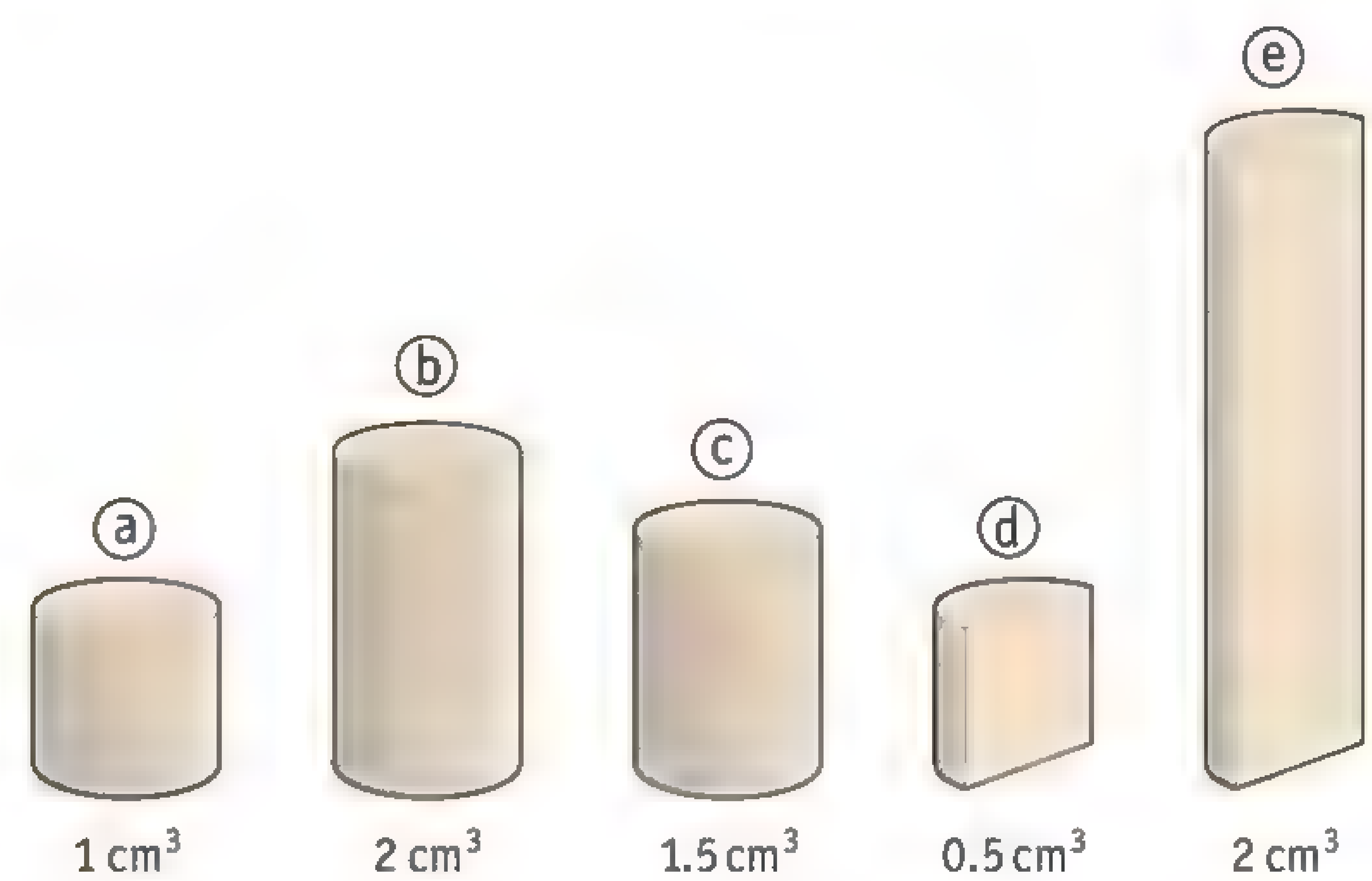


▲ figure 40
Measuring the oil level with a dipstick.

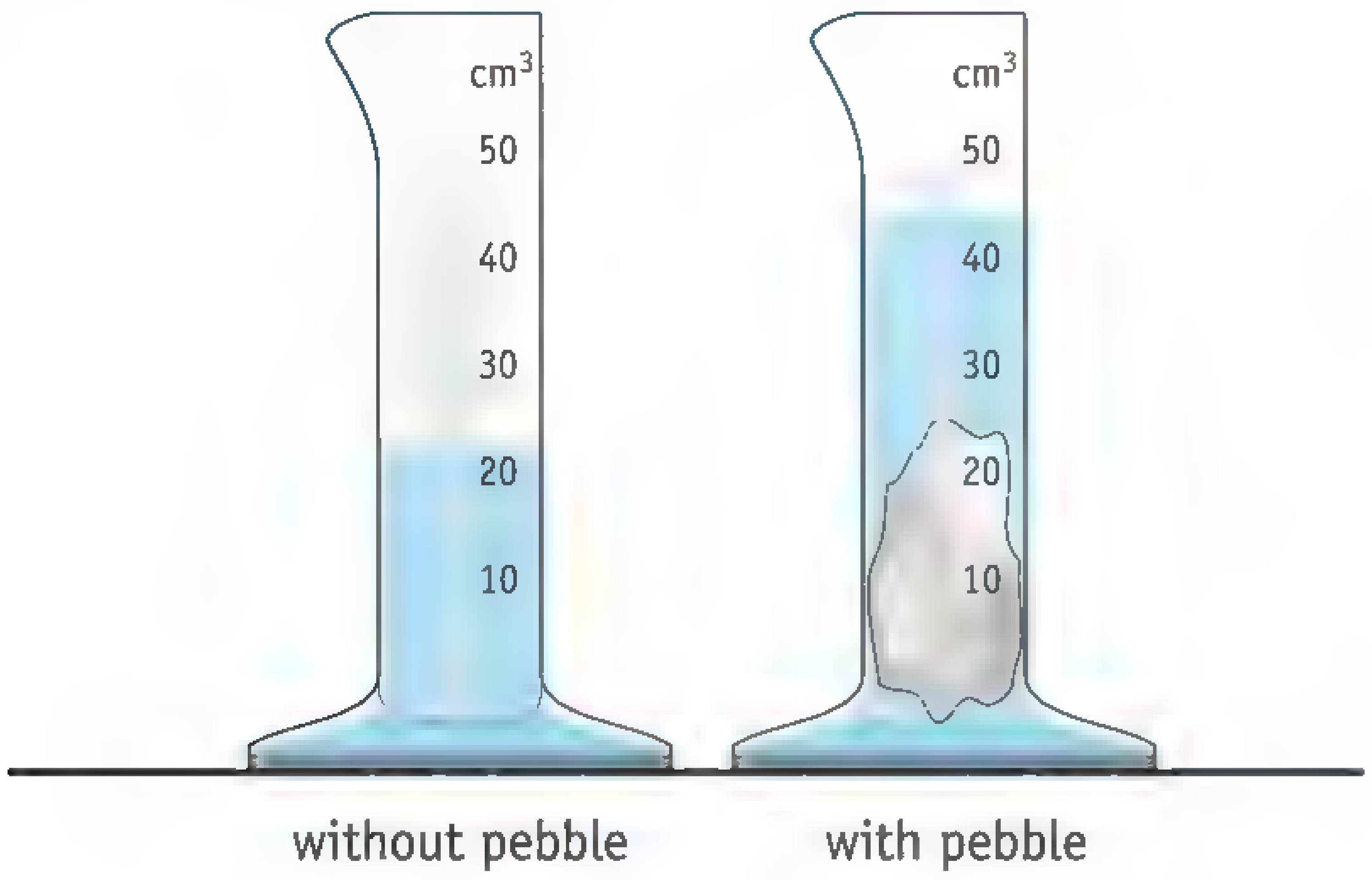
12 The packaging of a vanilla ice cream says: 90 mL/50 g. They are also available in packs of one litre.
How many whole ice creams of 90 mL can be made from the one-litre pack?

13 The label of a bottle of cordial says:
0.75 L | 850 g
What is the density of the cordial?

14 Yvonne is cutting various pieces of wood from a broomstick (figure 41).
a Which pieces have the same mass?
b Which pieces have the same density?



▲ figure 41
five pieces from a broomstick



▲ figure 42
This is how Tom determines the volume of the pebble.

15 Tom lowers a pebble into a measuring cylinder containing water (figure 42).
What is the volume of the pebble?

16 The mass of the pebble in figure 42 is 55 grams. Calculate the density of this type of rock.

17 The word 'pure' is used differently in everyday life than in physics and chemistry.
- **a** What would you mean by 'pure drinking water' in everyday speech'?
- **b** What does a chemist mean by a 'pure substance'?

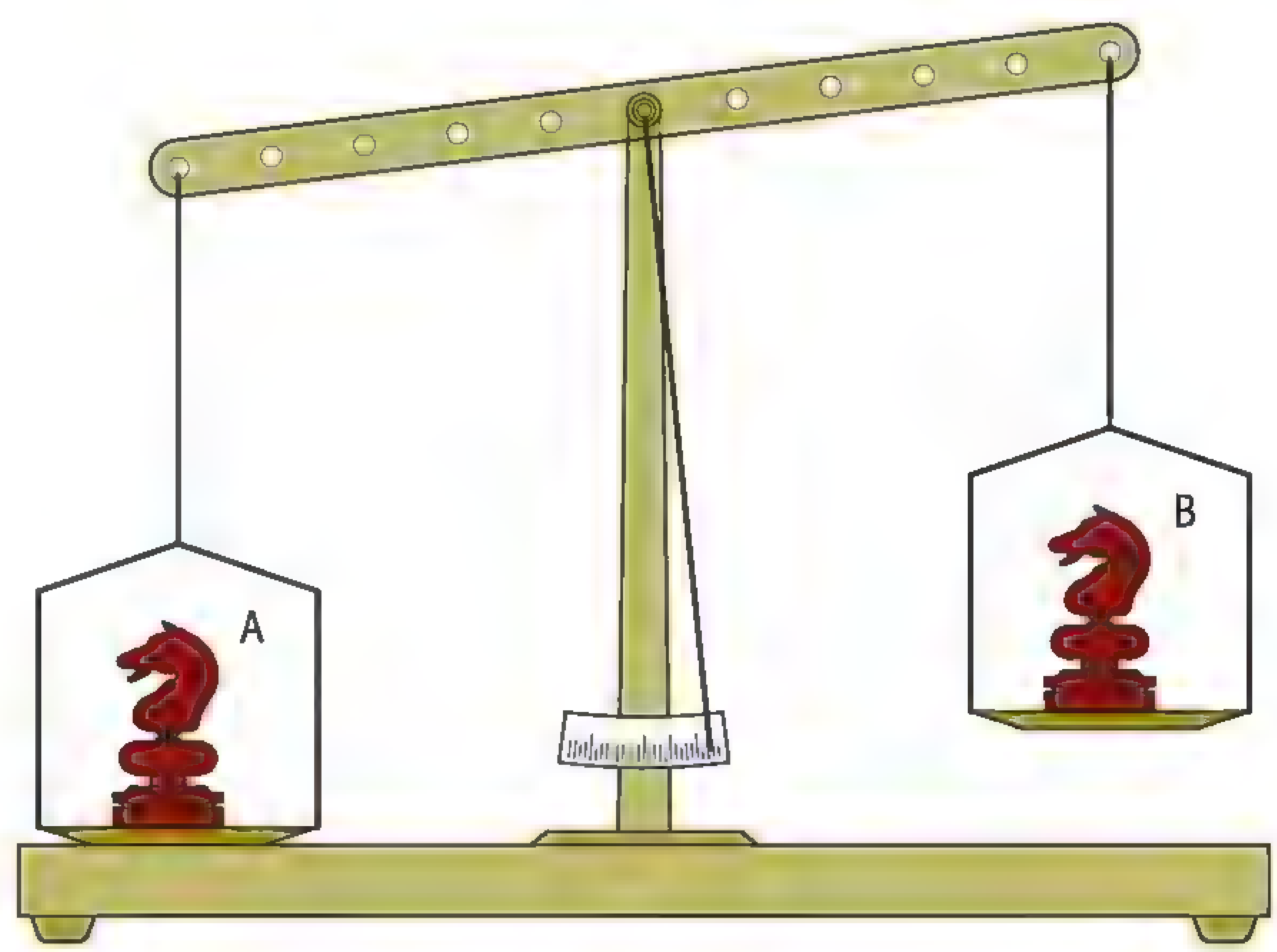
18 Alison is given a glass beaker of seawater with which to do an experiment. First of all, she has to determine the mass of the seawater. She can't just pour the water out of the glass and onto the scales, of course. How can she still determine the mass of just the seawater (without the glass)?
- **a** Describe what Alison could do, step by step.
- **b** Underline the tools or equipment she needs for the job.

19 The label on a box of cylindrical candles is shown in figure 43.
Use the information on the label to calculate the density of the material from which the candles are made.

▶	**30 candles, 1.5 kg**
▶	Length 18 cm, diam. 20 mm
▶	approx. 6 hours burning time per candle
▶	Place the candles vertically and at least 10 cm apart Do not place candles in draughts or in warm air flows Keep the area around the wick clean Long wicks can produce soot; cut the wick down to approx. 1 cm if necessary Do not use water to extinguish

▲ figure 43
the label on a box of candles

20 Two chess pieces have been put on a balance (figure 44). One chess piece is made of silver (10.5 g/cm³) and the other is made of gold (19.3 g/cm³). You can't see which is which from the outside, because both have been painted brown.
Work out which chess piece is made of gold. Write down all the steps in your reasoning carefully.



▲ figure 44
a silver knight and a gold knight

Nova © Uitgeverij Malmberg

Gold

Genuine or fake?

Gold is a yellow and shiny metal. But ‘all that glitters is not gold’. In the past, when gold coins were still in circulation, people in the market would sometimes bite a gold coin to see if it was real. Pure gold is so soft that you would leave teeth marks in it. It seems as if elite athletes have taken over that habit. At the Olympic Games, the winners always seem to bite their medal for a moment, even if nobody knows why any longer.

When is an object really made of gold? We asked an expert: Jeanne Derksen, a professional jeweller and gold buyer. “Well,” she says, “if what you mean by ‘gold’ is 100% pure gold, the answer is ‘never’. Coins and jewellery are not made from pure gold, because it is much too soft. It’s always an alloy – a mixture of gold with other metals. An alloy is harder and scratches less easily than pure gold.”

“Gold isn’t always yellow either,” explains Ms Derksen. “Pure gold is, of course, but gold alloys can be all sorts of colours. You can get white gold, red gold, green gold and even purple gold. The colour you get depends on the metals in the mixture. Gold jewellery is often made of alloys that contain a lot of silver. That makes them bright yellow, unlike pure gold, which is a warm orange-yellow. Alloys with a lot of copper, on the other hand, have a red shine.”

“A piece of jewellery made of 14-carat gold in is fact just a little more than half gold.”

Hallmarks

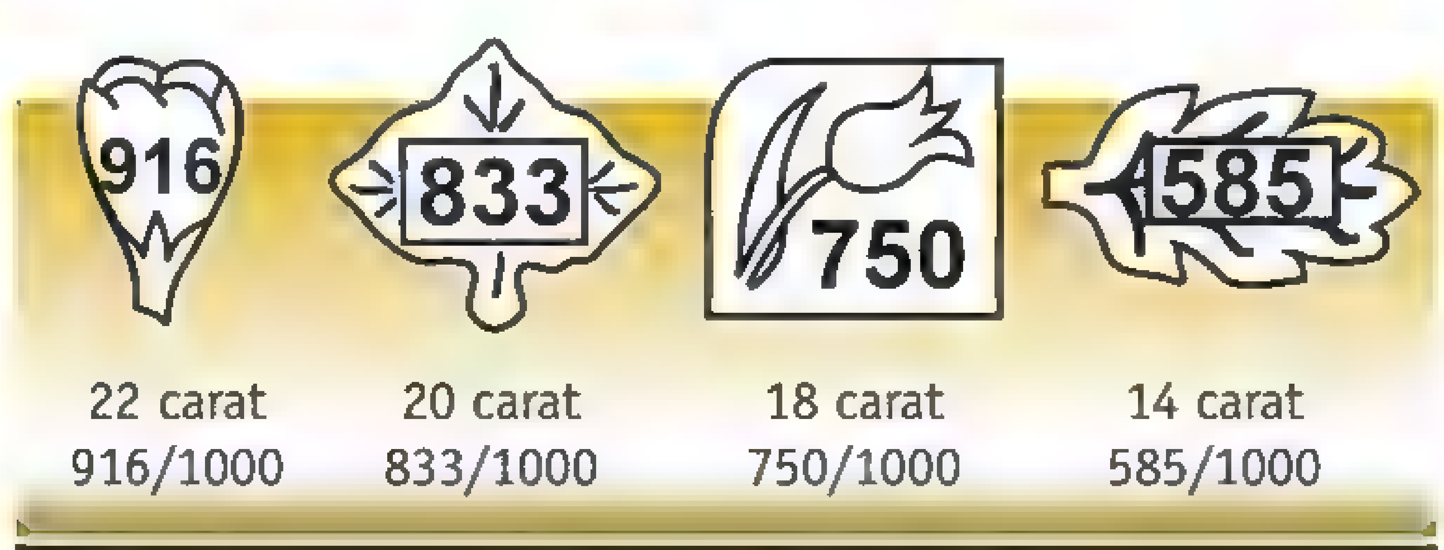
So how can you find out how much gold an object contains? Ms Derksen explains: “You can tell that from the hallmark that is stamped into it. Every country has its own hallmarks. This is the Dutch hallmark:

It means for instance that the alloy used contains 750/1000 pure gold, i.e. it is three quarters or 75% pure.”
“But,” she says, “jewellers have their own way of indicating the gold content. They use a special unit: the carat. This is a scale that goes from 0 to 24 carats. 0 carats is 0% gold, 6 carats is 25% gold, 12 carats is 50% gold, 18 carats is 75% gold and 24 carats is 100% gold. If you see a 750 hallmark on an object, a jeweller will say that it is made of 18-carat gold.”

The gold content of ‘gold’

Four types of alloy may be used in the Netherlands for gold jewellery. Each type of alloy has its own hallmark. “These four alloys are simply called ‘gold’ in the shop,” explains Jeanne Derksen, “although it’s not pure gold, of course. A piece of jewellery made of 14-carat gold is in fact just a little more than half gold.”

“Other countries have other rules. In the United States, ‘10K gold’ – which is actually less than half gold – is very popular. A Dutch jeweller isn’t allowed to call that gold, but the Americans aren’t so fussy. So now you can immediately see why gold jewellery is so cheap in the USA...”



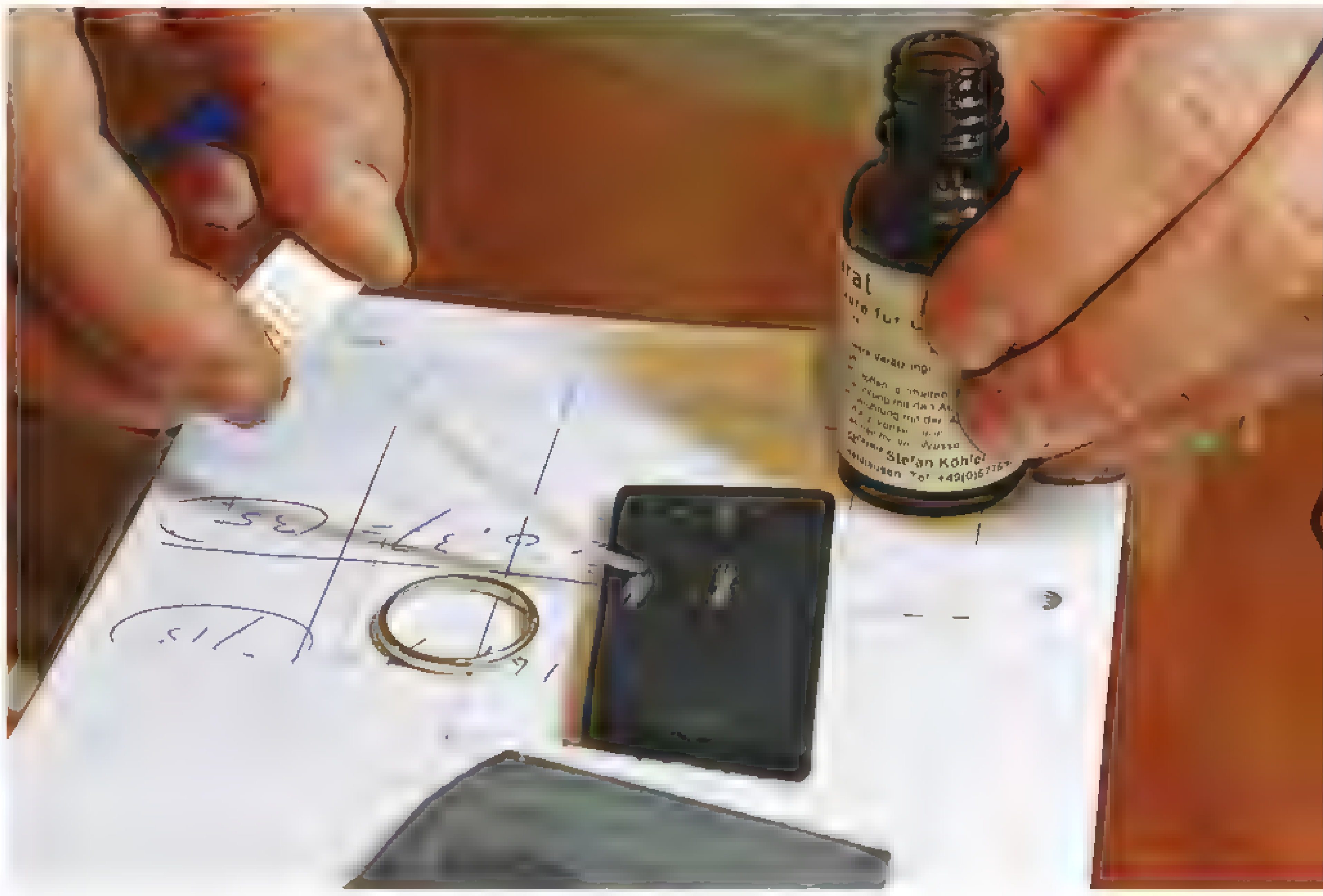
Testing gold

But how can you find out if it is correct? After all, surely hallmarks can also be forged? Ms Derksen says that she first has a good look at the object. "Sometimes you can see from a worn patch that it is gilded copper or silver. I also have a good look to see if the metal has been eroded. If so, you know that the gold content can't be very high."

Then she shows how she would test a gold bracelet. She puts three vials on the table. "Careful with those," she says, "they are corrosive acids that you most definitely must not get on your clothes or on your skin." She points to a vial labelled '14K'. "We call this liquid '14-carat water'. But don't be fooled – it's nitric acid, very nasty stuff. Most metals dissolve in it quickly, but 14-carat gold or purer can withstand it."

Ms Derksen takes the bracelet and rubs it firmly over a touchstone, a square piece of slate with a smooth surface. It leaves a yellow streak on the stone. She puts a few drops of the testing solution carefully onto the mark, but nothing happens. "That's exactly what you want to see," she says. "If the streak doesn't dissolve, then you know that it's real gold, at least 14 carats."

She makes a new mark on the touchstone and now takes the small bottle labelled '18K'. This time, the yellow streak disappears immediately when she puts a couple of drops of the test liquid



"Other countries have other rules. In the United States, '10K gold' – which is actually less than half gold – is very popular. A Dutch jeweller isn't allowed to call that gold, but the Americans aren't so fussy. So now you can immediately see why gold jewellery is so cheap in the USA..."

on it. “You can see that the gold does dissolve now,” she says. “That means that the gold content is less than 18 carats. It’s probably 14-carat yellow gold, which is a popular alloy.”

Density

“This was just a quick initial test,” says Ms Derksen, “but it gives you an idea of how the gold content can be tested. If the result matches the hallmark, that’s usually enough to be sure. If not, you can also determine the density as an extra check. That’s another method that also gives reliable results.”

Jeanne Derksen shows a table that gives the densities of various gold alloys. “Most forgeries use silver and copper,” she tells us. ”But gold is extremely heavy; its density is much higher than silver or copper, which is useful for us. A forgery can look deceptively realistic, particularly if you don’t work with gold every day. But if you determine the density, a forgery will be shown up for what it is, every time.”

Believe it or not, an Olympic gold medal would also fail the test. The gold medals from the 2012 Olympics, for example, only contain 1.34% gold – the rest is silver and copper. A medal weighing 450 grams contains just 6 grams of gold, in a thin layer on the outside. It’s just as well that the athletes don’t bite down hard on their gold medals. Otherwise they might lose a few teeth...

▼ **table** the densities of a number of gold alloys (g/cm³)

	585 / 14K	750 / 18K	916 / 22K	100 / 24K
yellow gold	13.6	15.5	17.8	-
red gold	13.0	15.0	17.6	-
pure gold	-	-	-	19.3

Exercises

1 The text lists three ways of testing gold objects.
What property of the substance gold helps you recognise ‘real gold’:
a when you bite down firmly on an old gold coin?
b when you use nitric acid to test a ‘gold streak’ on a touchstone?
c when you measure the mass and volume of a gold object?

2 Leona bought a bracelet on holiday that was made of ‘9-carat gold’.
a Can this alloy be called ‘gold’ in the Netherlands? Explain.
b Show that 9 carats is the same as 375/1000, or 37.5%.

***3** The density of 18-carat ‘yellow gold’ is greater than the density of 18-carat ‘red gold’.
a Which metal is pure gold alloyed with
– to give the bright yellow colour of ‘yellow gold’?
– to give the red sheen of ‘red gold’?
b Compare the densities of the metals that you have given in your answer to question a.
Why is ‘yellow gold’ denser than ‘red gold’?

3 Water

The weather

The weather can affect a lot of activities. A party seems much less fun if it is pouring with rain. People who enjoy their winter sports cannot go skiing if there is not enough snow. Fog and freezing rain can disrupt traffic enormously.

1 Ice, water, water vapour

▲ figure 1
Frost consists of lots of small ice crystals.

Rain, snow, mist, hail, frost and dew all look very different. Rain consists of transparent droplets, snowflakes are white and feathery, fog is a thick grey cloud that stops you being able to see much of the world around you, and dew forms as clear droplets. Nevertheless, all these weather types involve the same substance: water.

Solid, liquid and gaseous

Like many other substances, water can exist in three different states:
– as a **solid substance:** ice;
– as a **liquid:** water;
– as a **gas**: water vapour.
These three states are also referred to as **phases.**

Snow, hail and frost all consist of ice (figure 1). If you pick up a handful, ice will melt in the warmth of your hand and only a little water will remain. Rain, mist and dew consist of water droplets. You can often see the drops clearly in rain and dew, but in fog or mist they are microscopically small.

▲ figure 2
The low air temperature allows small visible 'clouds' to be formed.

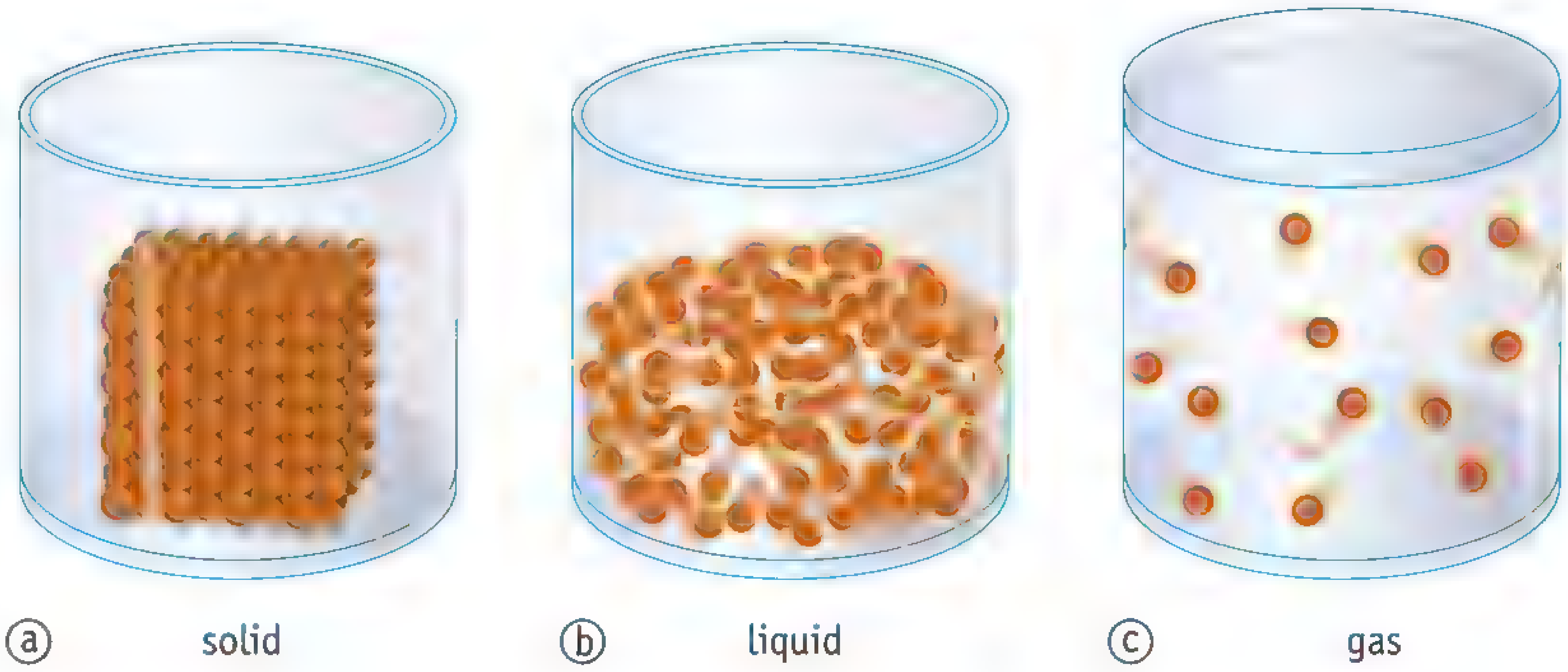
The problem with water vapour is that you cannot see it. The term 'water vapour' is often used for a cloud that consists of very small droplets of water, but that is incorrect. A cloud consists of liquid water, even though the individual droplets are so small that you cannot see them. Water vapour is not a mist: it is an invisible gas in the air all around you. There is a relatively large amount of water vapour in the air that you exhale. You do not normally see that. But when the weather is cold, the water vapour in your breath can change into very small droplets of water because your warm breath cools down in the cold outside air. Then you can see a small cloud of mist appearing in front of your mouth (figure 2).

Phases in the particle model

Although you cannot see how the molecules in a substance such as water behave, you can try to imagine it. You can try to picture what the molecules are doing and how they affect one another. This lets you get an idea of what a substance actually is. This kind of picture is also called a 'model' of the substance.

In physics and chemistry, the **particle model** is widely used. In this model, a substance is always made up of the same molecules, no matter whether the substance is solid, liquid or gaseous. A substance can exist in different phases because the molecules are able to move in various ways (rather than because the molecules themselves change in any way).

Solid
In a solid substance, all the molecules have their own 'fixed' or base positions (figure 3a). The molecules are not entirely still: they are vibrating back and forth around an average 'equilibrium position', but without losing their base position with respect to the other molecules. A block of ice therefore has not only a fixed shape but also a fixed volume.

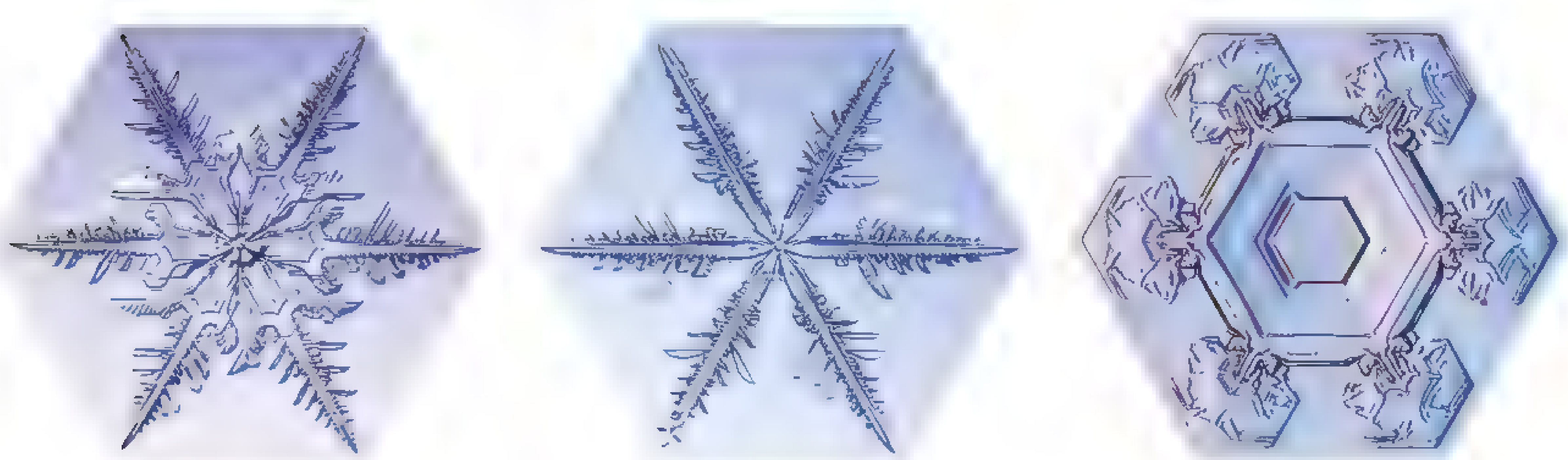


▶ figure 3
the molecules in a solid, a liquid and a gas

Liquid
In a liquid, the molecules do not have a base position. They can move back and forth past one another in any direction (figure 3b). Because the molecules are not fixed in a given position, a water drop does not have a fixed shape. However, the molecules do remain as close to each other as possible. That means that a drop of water does have a fixed volume.

Gas
The molecules in a gas move freely and independently of one another. They spread out to fill the space that the gas is confined in (figure 3c). The average distances between them are very large. The molecules do not affect one another, except when they collide. A gas such as water vapour therefore has neither a fixed shape nor a fixed volume.

Crystals
Snow is made up of ice crystals that have all kinds of beautiful shapes. All those shapes have the same type of six-sided structures, though. This **crystal structure** is typical of ice (figure 4). Many solid substances have their own distinctive crystal structures.



▶ figure 4
The ice crystals in snow have a distinctive hexagonal structure.

▲ figure 5
a model of a crystal, with oranges instead of molecules

The particle model lets you explain why crystals have fixed shapes. Because the molecules in a substance are all identical, they can be 'stacked' in regular patterns, just like the oranges in a supermarket. (figure 5). This creates a **crystal lattice** in which every molecule has a base position.

Crystals can be microscopically small, but can also be several centimetres in size. A piece of rock crystal is made up of large individual crystals that have grown together. The crystal structure can then be seen clearly with the naked eye (figure 6).

▶ figure 6
a piece of rock crystal

Plus Cohesion and adhesion

▲ figure 7
a dripping tap: an example of both cohesion and adhesion

Molecules of the same substance attract each other. This is known as **cohesion.** There may also be attractive forces between molecules of different substances. This is known as **adhesion.** Cohesion is the reason why a water droplet assumes a spherical shape: the molecules pull together as tightly as possible. Adhesion is why a drop of water will hang from a tap (figure 7).

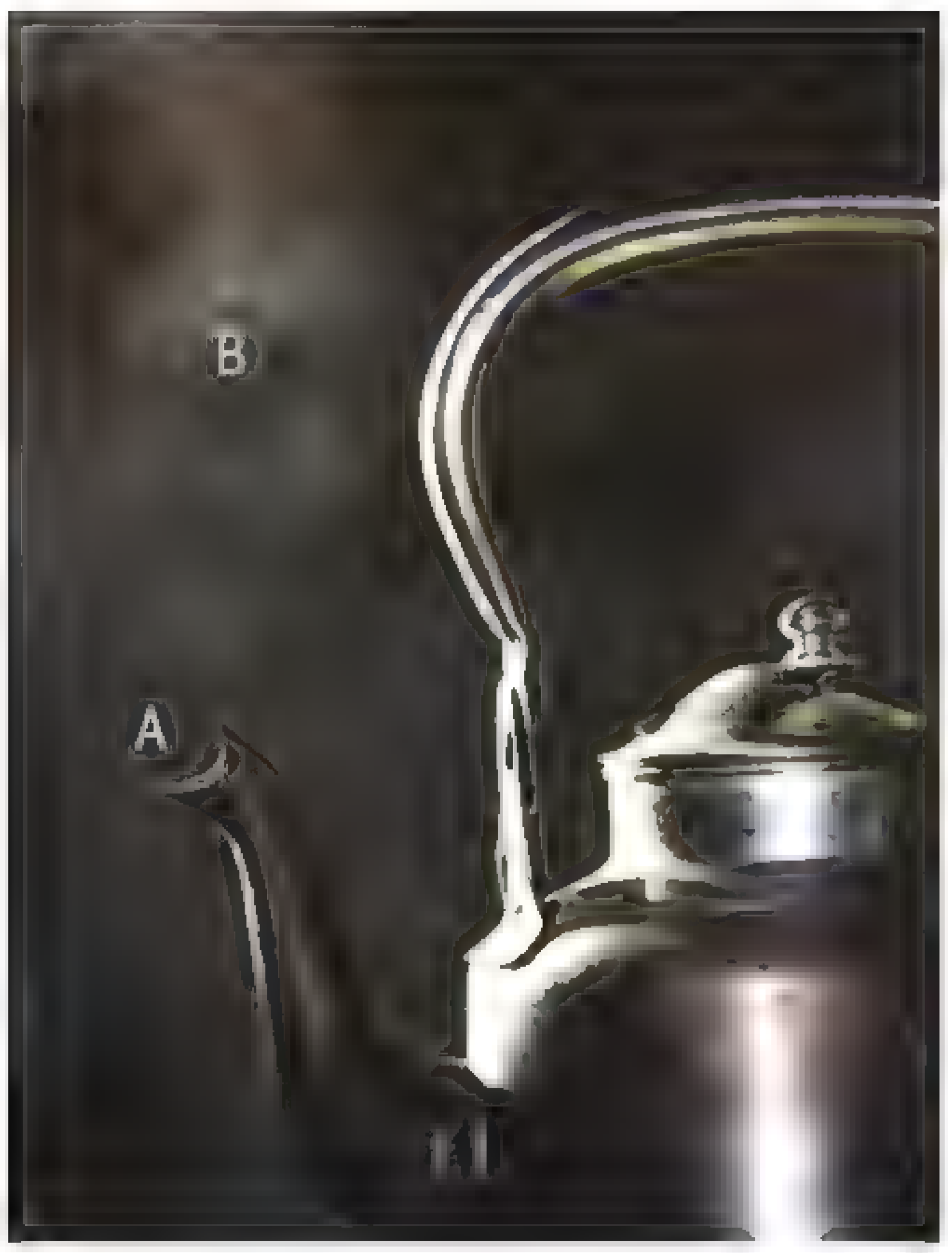
If you dip one end of a sugar cube into water, the cube will suck up water until it is wet through. This is because the adhesive forces (between the sugar molecules and the water molecules) are much greater than the cohesive ones (between the individual water molecules). This means that the water is soon attracted into the small gaps between the sugar granules.

When materials such as kitchen paper or cotton absorb water, this is because the adhesion is greater than the cohesion within the water. Precisely the opposite happens for some other substances. Drops of water remain on a greasy surface, for example, because there is no attraction between fat molecules and water molecules: there is no adhesion, only cohesion.

Exercises

1 What phase is water in for each of the following weather types?
a rain
b snow
c hail
d fog
e frost

2 According to the particle model, how are the molecules moving in:
a a solid?
b a liquid?
c a gas?



▲ figure 8
What phases is the water in?

3 A water droplet does not have a fixed shape, but it does have a fixed volume.
Give an explanation of this using the particle model.

4 Figure 8 shows you a kettle of boiling water.
a What phase is the water in at A? How can you see that?
b What phase is the water in at B? How can you see that?
c Hot water vapour is also often called steam.
Where is the water present as steam, at A or at B? Explain your answer.

5 Fog or mist consists of small droplets of liquid water.
What makes you notice that when you are walking or cycling through thick mist?

6 The photo in figure 9 was taken shortly after a shower of freezing rain. The freezing rain has created a transparent layer on a branch.
a What phase was the water in when it hit the branch? How can you see that?
b What phase was the water in when the photo was taken? How can you see that?

▶ figure 9
a close-up of a layer of frozen rain on a branch

7 Fuels can be in solid, liquid or gaseous form.
Give an example from everyday life of:
- a a solid fuel.
- b a liquid fuel.
- c a gaseous fuel.

8 Search the Internet for information about snow crystals.
- a Collect a number of photographs of differently shaped snow crystals.
- b How is it possible for snow crystals to have so many different shapes?
- c What does the crystal structure look like that you can see in all those shapes?
- d What explanation can you give for the fact that this same structure arises every time?

*9 Use the particle model to explain why:
- a it is easy to compress a gas but not to compress a liquid.
- b a crystal can only be split neatly into two (cleaved) in particular directions.
- c you soon smell that a gas tap is open everywhere in the classroom.

▲ figure 10
The surface of the water (left) has a concave meniscus, whereas the mercury (right) has a convex meniscus.

Plus Cohesion and adhesion

10 What is the name for the attractive force:
- a between molecules of the same substance?
- b between the molecules of different substances?

11 Use the concepts of cohesion and adhesion to explain:
- a why a drop of water hanging from a tap takes on a spherical shape (figure 7).
- b why the shape of the meniscus (curved surface) of the water in a test tube is concave (figure 10).
- c why you can write on a blackboard or paving stone with a piece of chalk.
- d why you can dab up spilled water again quickly with a sheet of kitchen paper.
- e why water drops roll off the feathers of a duck without wetting them.

2 Temperature

▲ figure 11
A meteorologist reading the temperature.

The weather forecast warns us about slippery conditions if temperatures 'below zero' are expected. Wet parts of the roads can then freeze, creating an extremely slippery layer of 'black ice' on the road surface. When the temperature of the air outside rises above zero the ice will thaw and the slippery conditions will disappear again. A weather thermometer lets you check whether the predictions in the weather forecast were correct or not.

Measuring the temperature

Your perceptions of heat and cold are not terribly reliable. Luke-warm water can feel hot if your fingers are cold. When it is windy in the winter, it seems colder than it actually is: the more wind there is, the colder it feels – even if the temperature stays the same.

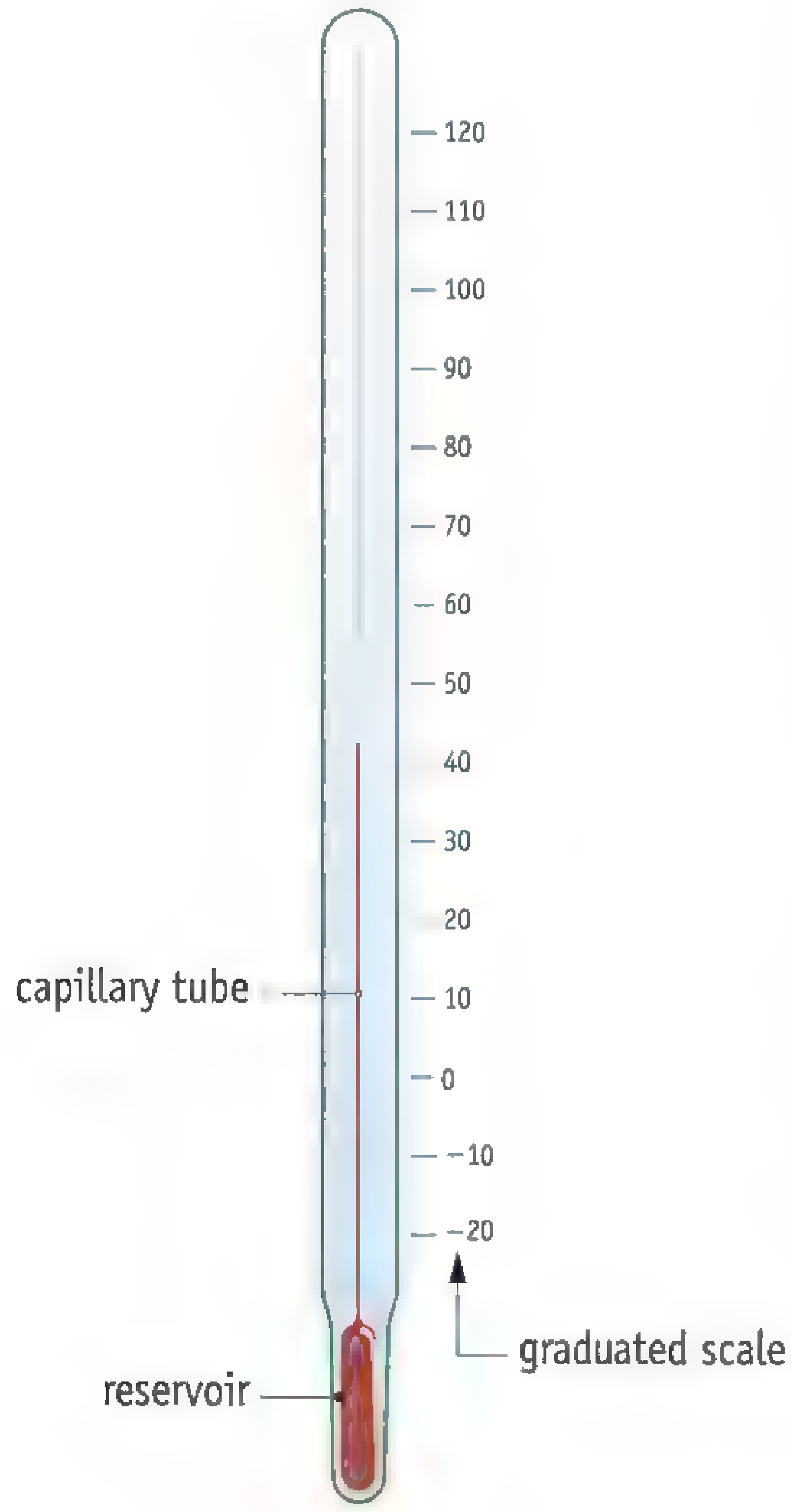
A **thermometer** lets you measure the **temperature** of the air around you. This gives you a numeric value for temperature that is independent of your own perceptions. You might think it's "bitterly cold" when somebody else just says it's "nice and fresh." But if you have a thermometer that is working properly, you will both get the same value for temperature.

If you hang a thermometer up in the sun, it will show a temperature that is higher than the outside air (just as your skin also warms up if you sit in the sun – you only notice that the air is not so warm after all when a cloud goes in front of the sun). A thermometer that is hung up in the sun can therefore not give the right value for the air temperature.

That is why meteorologists hang their thermometers up 1.5 metres above the ground, in a cabinet that has been painted white. The walls of one of these weather station 'huts' have openings that the wind can circulate inside it freely (figure 11). The thermometers in the weather cabin are at the same temperature as the air flowing past them. This gives a reliable measurement of the temperature.

The liquid thermometer

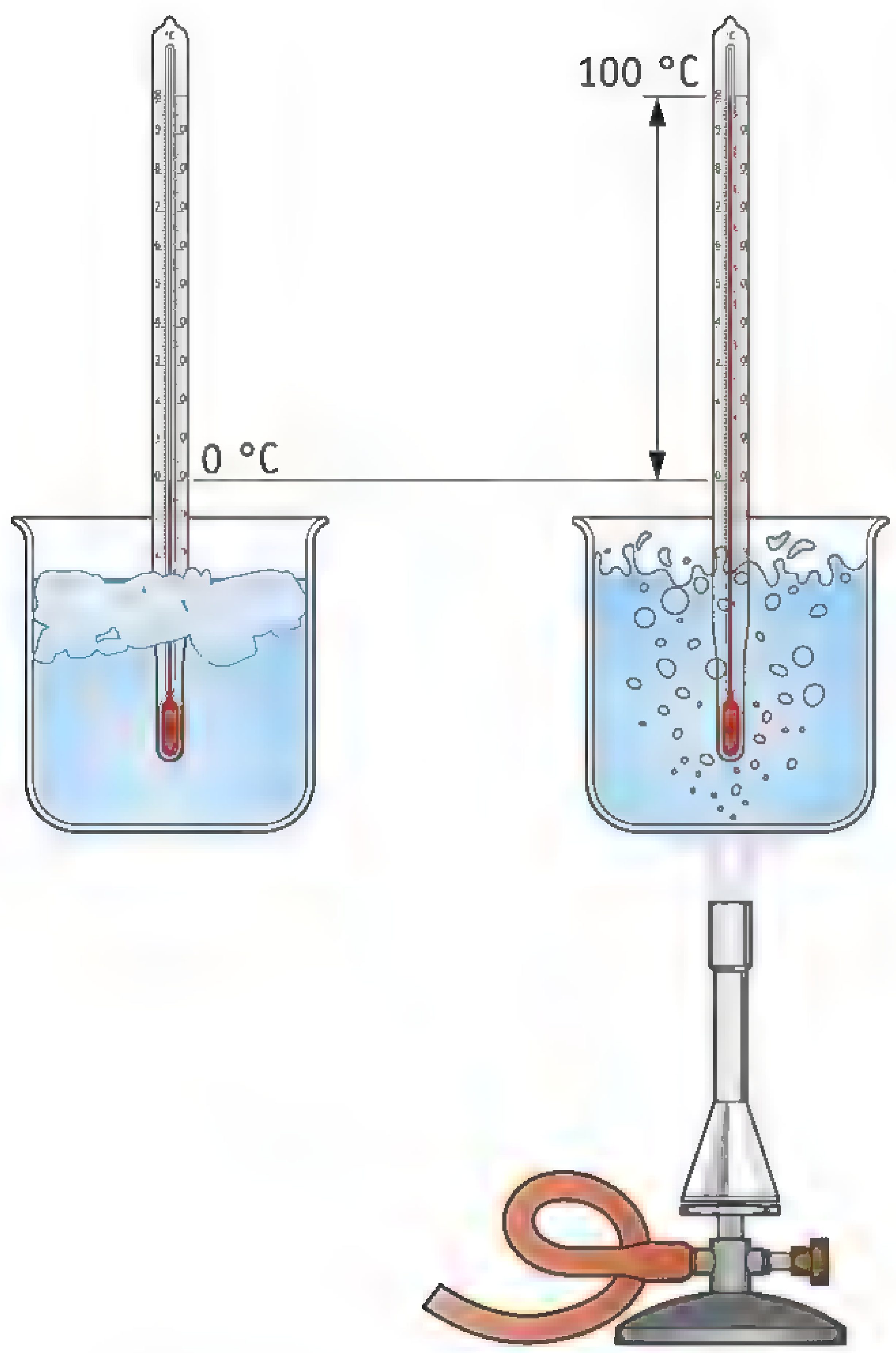
One well-known type of thermometer is the **liquid thermometer.** This type of thermometer consists of a **reservoir** and a **capillary tube** with a **graduated scale** alongside (figure 12). The reservoir and part of the capillary tube are filled with a liquid. Modern thermometers use alcohol, with a dye added to make it easier to see.



◀ figure 12
a liquid thermometer

When the temperature increases, the liquid in the capillary tube expands. The level of the liquid in the tube goes up. When the temperature decreases, the liquid contracts again and the liquid level falls. Because the capillary tube is very narrow, you can see the liquid rise or fall with just small temperature differences.

You read off the temperature by comparing the height of the liquid against the graduated scale on the capillary tube. In daily life, thermometers are used with graduated scales marked in **degrees Celsius** (0 °C). This graduation is also known as the centigrade scale.



▲ figure 13
making a graduated scale for temperature

The difference between the highest and lowest temperatures that you can measure with a thermometer is known as the **measurement range** of the thermometer. The measurement range of the thermometer in figure 12 is from –20 to 120 °C.

The Celsius scale

Experiment 1

Figure 13 shows how you can add a graduated scale in degrees Celsius to an unmarked thermometer:

1 Mark the zero point (0 °C) as the level of the liquid at the temperature of melting ice.
2 Mark the hundred point (100 °C) as the level of the liquid at the temperature of boiling water.
3 Add lines to divide the distance between these points into ten equal parts. Each of these lines then represents a difference of 10 °C.
4 Finally, add more lines with the same spacing between them below the zero point and above the hundred point.

It is therefore simply a question of everyone agreeing that the melting point of water is exactly 0 °C and the boiling point of water is exactly 100 °C.

Clinical thermometers

Special liquid thermometers were used in the past for measuring your body temperature. The measurement range of one of these **clinical thermometers** is 35 °C to 43 °C. The capillary tube is narrower and the reservoir larger than in normal liquid thermometers. That is why there is so much space between the degree markings, letting you read the temperature easily to an accuracy of a tenth of a degree.

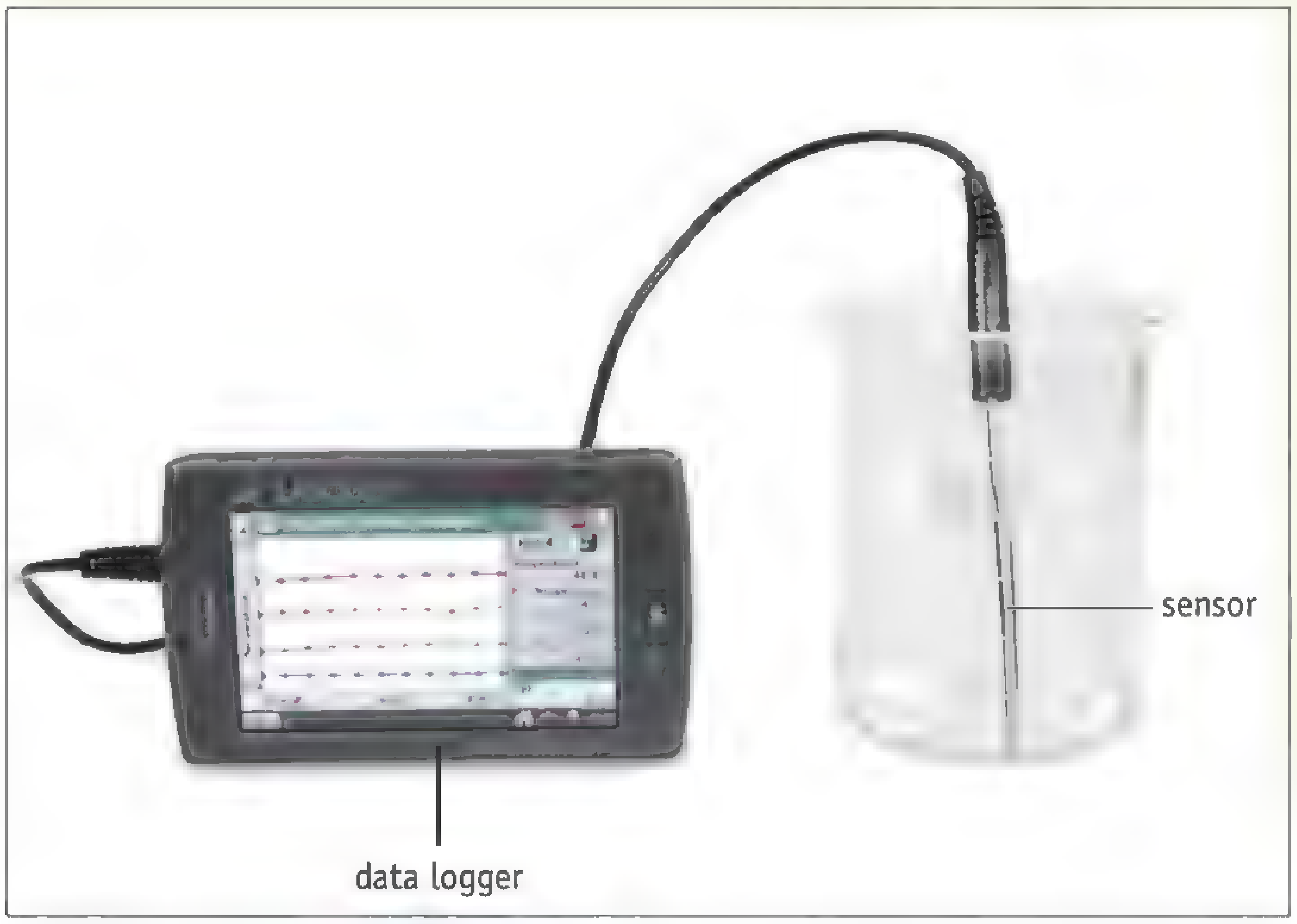
Nowadays, digital clinical thermometers are used. This type of thermometer shows the temperature in numbers on a small screen. This lets you see at a glance what your body temperature is (figure 14). A digital thermometer does not contain a liquid that expands and contracts as the temperature rises or falls. Instead, it works electronically.

◀ figure 14
a digital ear thermometer

Plus Measuring with a data logger

It is sometimes interesting to know how the temperature changes over the course of a given period. The setup shown in figure 15 lets you measure that automatically. The **sensor** produces an electrical signal that varies depending on temperature. The **data logger** – a small, specialized measurement computer – uses that signal to work out what the temperature is.

You can set how long you want the data logger to make measurements for (e.g. for eight hours) and how often (e.g. once a minute) on the data logger's screen. Everything is handled for you after you have started the measurements: the data logger stores the measurements automatically in a measurement file. If measurements are made once a minute for eight hours, the file will contain a total of 8 × 60 = 480 measured values (also referred to as 'samples').



The data logger can display the measurement results on the screen in various ways: as a table of numbers or as points on a graph. This type of graph shows the time along the horizontal axis and the temperature on the vertical axis. You can also connect the data logger up to a computer and examine the data on the computer screen.

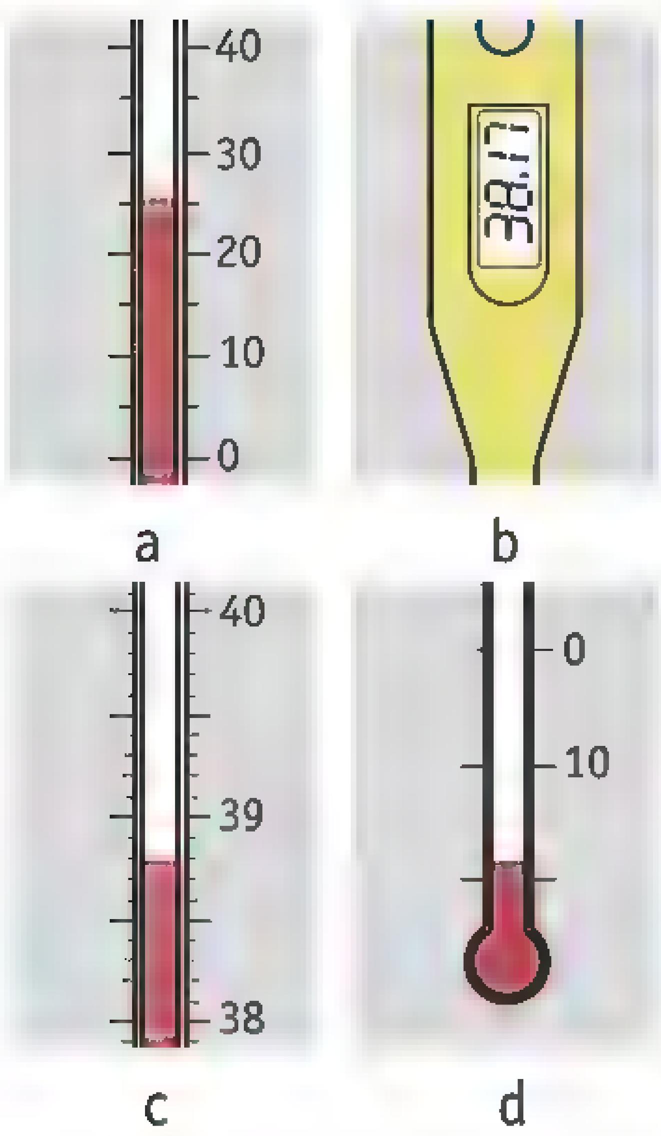
◀ **figure 15**
This setup lets you make a series of temperature measurements automatically.

Exercises

12 What are the three components of a liquid thermometer?

13 Describe in your own words how you can calibrate a thermometer with a graduated scale in degrees Celsius.

14 Natasha is going to do an experiment for which she needs a Bunsen burner.
What must Natasha check before she lights the burner?
See 'Skills 6' at the back of the book.



▲ figure 16
four thermometers

15 Figure 16 shows four different thermometers.
- **a** Read off each thermometer as accurately as possible.
- **b** Which thermometer is the easiest to read?
- **c** What is the name for a thermometer like this that is easy to read?

16 You need worksheet 3-1 for this exercise.
Harry has done an experiment using a liquid thermometer that has no graduated scale. He has marked the zero point and the hundred point. The worksheet shows Harry's thermometer. Determine the temperature it is currently showing as accurately as possible. Tip: make a graduated scale.

17 There is always a fixed distance between the degree markings on a liquid thermometer.
- **a** What would a thermometer manufacturer need to do to make that distance bigger?
  - A Make the capillary tube narrower and the reservoir smaller.
  - B Make the capillary tube narrower and the reservoir larger.
  - C Make the capillary tube wider and the reservoir smaller.
  - D Make the capillary tube wider and the reservoir larger.
- **b** What is the benefit of having a greater distance between the degree markers?
- **c** What are the disadvantages of having a greater distance between the degree markers?

18 In the mountains, you can sometimes sunbathe in your swimsuit although your deckchair is standing in the snow (figure 17).
- **a** How can you tell that the air temperature is still less than 0 °C?
- **b** How can you tell that the temperature of your skin is a long way above 0 °C?
- **c** Suppose that there was a thermometer in the sun next to your deckchair. Would the thermometer give a reliable value for the air temperature? Explain your answer.

▶ figure 17
sunbathing in the snow

▲ **figure 18**
the temperature scale for a car engine

19 Car engines are cooled using a coolant liquid. You can see the temperature of the coolant on the dashboard (figure 18).

- **a** How many sections is the temperature scale divided into?
- **b** What do the 'Hi' and 'Lo' indications mean?
- **c** Where will the needle point when the engine has just been started?
- **d** Why is this temperature scale more useful for a car driver than a scale marked in °C? Explain your answer.

***20** Search the Internet for information about the Fahrenheit temperature scale.

- **a** In what parts of the world are everyday temperatures measured in degrees Fahrenheit (°F)?
- **b** Copy and complete:
  0 °C = ...°F
  100 °C = ...°F
- **c** How many degrees on the Fahrenheit scale correspond to a one-degree rise in the Celsius scale?
- **d** Explain how you can convert a temperature from °C to °F, and vice versa.
- **e** At what temperature do the Celsius and Fahrenheit scales have the same numerical value?
- **f** Normal body temperature is 37 °C.
  What is that in °F?
- **g** On an American website, you read:
  "On my journey to find Tulsa's Salvation Army, I discovered I was very underdressed for the cold weather. I later learned the temperature went down to 32 that night (which for Tulsa, was very cold)."
  Where is Tulsa and how cold was it that night (in °C)?

Plus Measuring with a data logger

21 Temperature sensors can be found in all sorts of devices.
Copy table 1 and complete it.

▼ **table 1** four devices with temperature sensors

the sensor in a:	measures the temperature of:
central heating thermostat	the air in the room
electric oven	
electric deep-fat fryer	
baby bottle warmer	

22 Jessica has been investigating what happens when you heat a carton of chocolate drink in a glass beaker of hot water. She has used two sensors for this: one sensor in the chocolate drink and the other in the water. She has placed the carton of chocolate drink in hot water and started measuring straight away. Figure 19 shows how the data logger represents the changes in the temperature from that point on.

a Why is it useful to have the temperatures measured automatically for this experiment?

b How long did the experiment take (from the start of the measurements)?

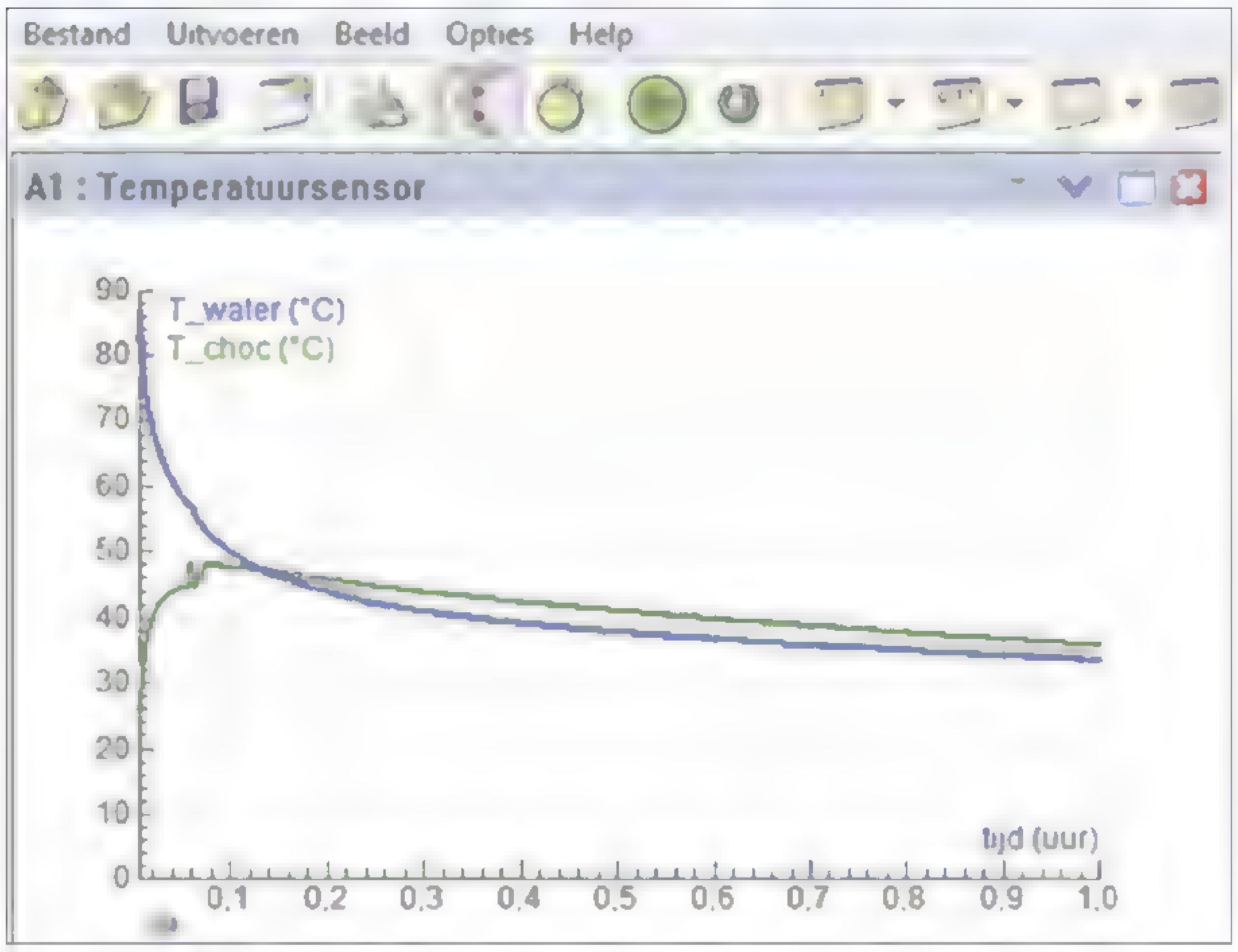
c What was the temperature of the water when the experiment was started?

d What was the temperature of the chocolate drink when the experiment was started?

e What was the highest temperature that the chocolate drink reached?

f After how many minutes was the highest temperature reached?

g What do you notice about the progression of the temperatures after about eight minutes? Try to give an explanation for this (think up a reason yourself).



▶ figure 19
Jessica's measurement results

Nova © Uitgeverij Malmberg

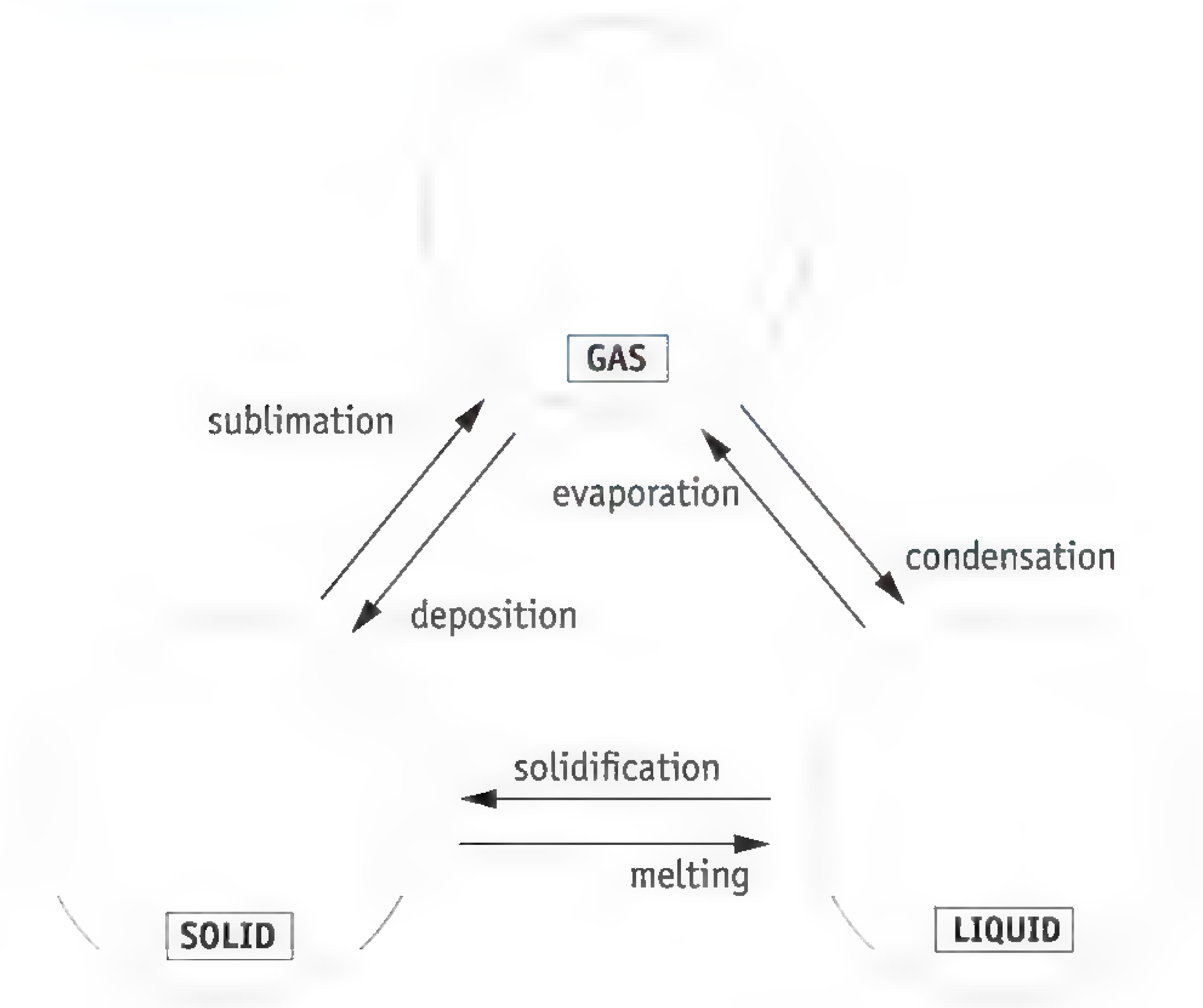
3 Phase changes

The weather can change suddenly. A summer's day can begin with a clear blue sky and end with a heavy thunderstorm. After a cold night in the winter, trees and shrubs can suddenly be coated with a thick layer of frost. When a thaw sets in, the ice that people were skating on the day before soon becomes unreliable. All these situations involve water changing phases.

Phase transitions

When water melts or freezes, this is known as a **phase transition**: the substance changes from one phase to another. There are six phase transitions (figure 20):

- **solidifying**/**freezing**: from liquid to solid
- **melting:** from solid to liquid
- **evaporation:** from liquid to gas
- **condensation:** from gas to liquid
- **deposition:** from gas to solid
- **sublimation:** from solid to gas



▶ figure 20
a diagram of the phase transitions

There are two common words for the transition from liquid to solid: freezing and solidifying. You say water 'freezes', but if you were talking about candle wax, you would say it 'solidifies'. The word generally used depends on the temperature: a liquid that becomes solid at temperatures of 0 °C or lower, is said to 'freeze'. If the same thing happens at a higher temperature, the word 'solidify' is used.

Phase transitions and the weather

The phase transitions of water play an important role in all sorts of weather phenomena:

Freezing

When it is freezing, a layer of ice appears on the water in puddles and ponds. The topmost layer of the water freezes: it changes from liquid to solid. If the temperature stays below zero, the layer of ice will thicken from the bottom.

Melting

When a thaw sets in, the layer of ice on puddles and ponds soon disappears. Tree branches that had been white with frost become bare again, and the droplets of water fall to the ground. Solid ice becomes liquid water.

▲ figure 21
Dew is made up of small water droplets.

Evaporation

When the sun shines after a shower, the road surfaces soon dry out again. Puddles become smaller and finally disappear altogether. This happens because the rainwater rapidly evaporates in warm weather: the visible water becomes invisible water vapour.

Condensation

When warm air cools down at night and meets a cold object, the water vapour in the air condenses out of it. Small droplets of water then appear on grass stems and leaves (figure 21). Invisible water vapour becomes visible water.

Deposition

If the temperature at night drops to below 0 °C, frost rather than dew is deposited. The water vapour in the air changes to small ice crystals that give a splendid white appearance to tree branches and blades of grass (figure 22).

▶ figure 22
Frost can give trees and shrubs a very different appearance.

Sublimation
If the air is very cold and dry, a layer of snow will gradually get thinner. This is because ice slowly changes into water vapour under those conditions. There are also substances that sublime rapidly, such as solid carbon dioxide ('dry ice').

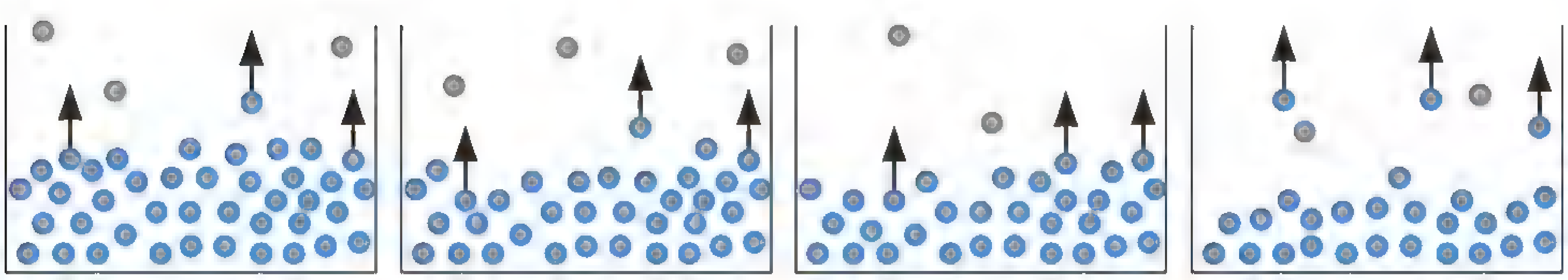
The influence of temperature

It is clear that the temperature plays a key role in the various phase transitions. The particle model lets you explain why. Let's look at the phase transitions of melting and evaporation as examples.

Melting in the particle model
In a solid substance, the molecules are stacked closely together in a regular pattern. There are attractive forces between adjacent molecules (ones that are next to each other). This makes sure that every molecule stays in its base position. The smaller the distance between two adjacent molecules, the greater the attractive force between them.

When the temperature increases, the molecules will vibrate increasingly vigorously. The distances between the molecules then become greater, as you can see from the fact that the substance expands. The greater distances mean that the attraction between the molecules becomes weaker. When the temperature reaches a certain value (0 °C in the case of water), the attractive force is too weak to hold the molecules together: the substance then melts and becomes liquid.

Evaporation in the particle model
The molecules in a liquid are constantly in motion. The attractive forces between them ensure that they remain close together. The situation at the liquid surface is different, though. Every now and again, a molecule there may have enough speed to escape from the liquid (figure 23). A molecule that does that will then become part of the air above the liquid. Little by little, the liquid loses more and more molecules: the liquid evaporates.



▲ figure 23
Evaporation occurs when molecules escape from a liquid.

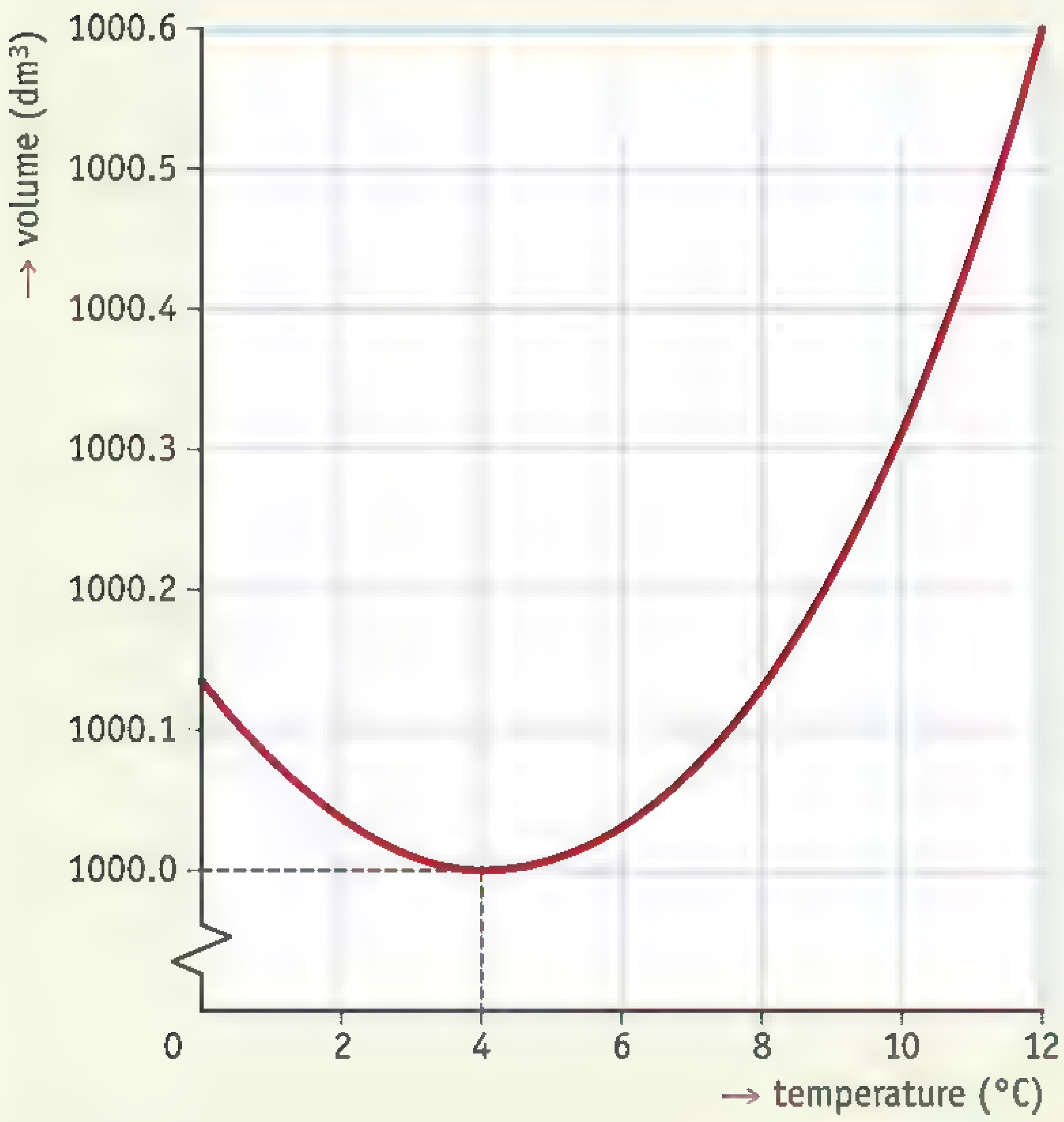
The higher the temperature, the greater the average speed of the molecules and the more easily they can escape from the liquid. Liquids therefore evaporate more quickly as the temperature increases.

Plus Water: an exception

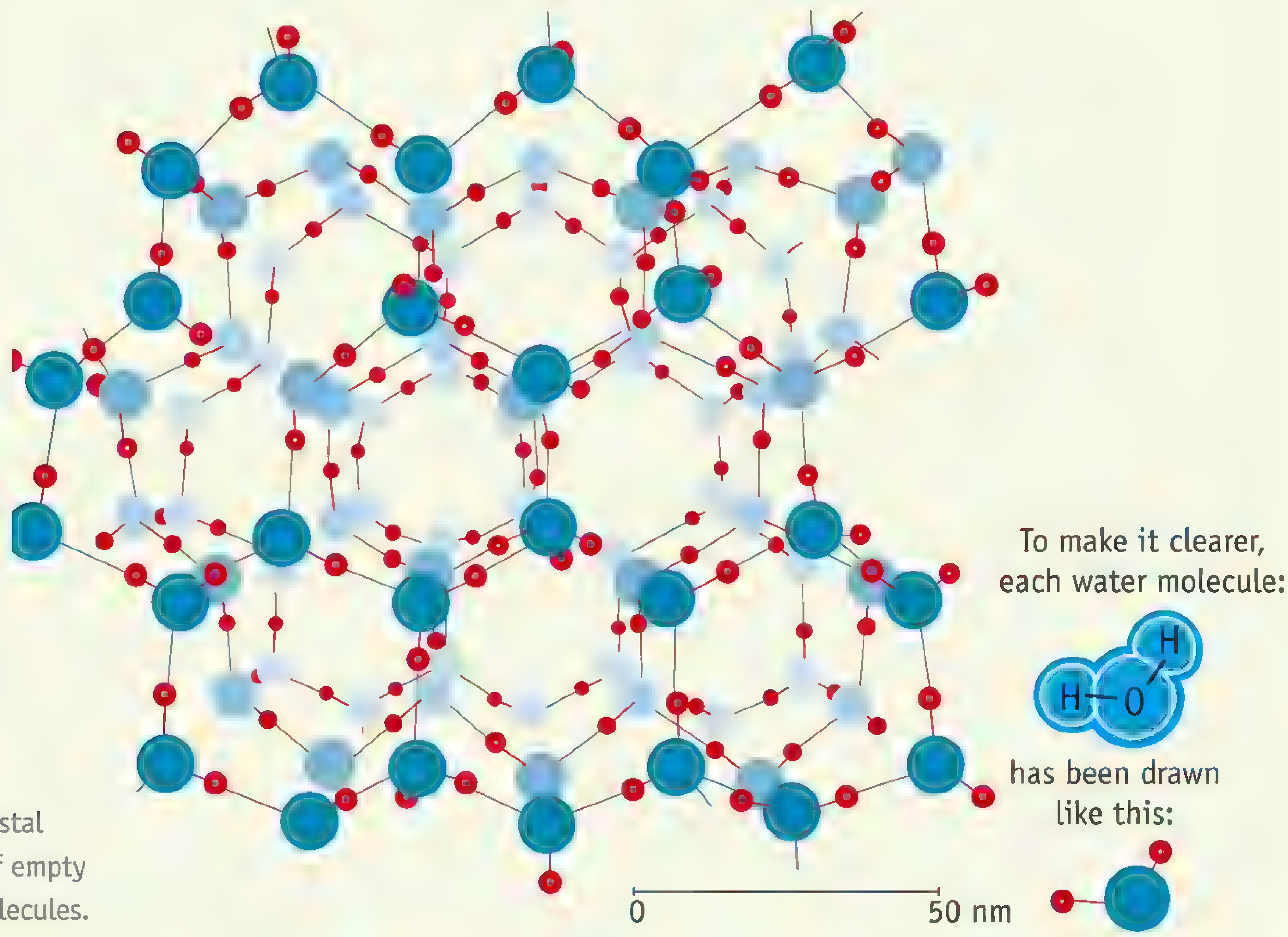
Almost all liquids shrink as the temperature decreases. Because the molecules are moving more slowly, they collide less vigorously and push each other away less. However, there is one important exception to this rule: water between 4 °C and 0 °C. When water cools down, it contracts like any other liquid until the temperature decreases to 4 °C. But when water cools beyond that, from 4 °C to 0 °C, it actually starts expanding again (figure 24).

If the water then freezes, it expands further: if 1 dm^3 of water at 0 °C freezes, it makes about 1.1 dm^3 of ice. The volume therefore increases by about 10% as water freezes. This is why you have to be very careful that water pipes do not freeze in the winter. The pipes can easily burst as they freeze.

The reason why water expands as it freezes is the unusual crystal structure of ice. The molecules form hexagons with a lot of free space between them (figure 25). This means that the average distance between the molecules is greater in ice than it is in water. The hexagons begin to form as soon as the water temperature falls below 4 °C, although no permanent crystal lattice is yet formed. This is why water is at its maximum density at 4 °C.



▲ figure 24
the expansion and contraction of water



▶ figure 25
Ice has an unusual crystal structure, with a lot of empty space between the molecules.

Exercises

23 Which phase transition is the reason why:
- **a** grass is wet with dew in the morning?
- **b** a road dries out again quickly after a shower of rain?
- **c** the branches of trees and shrubs get covered in frost?
- **d** a layer of snow gets thinner and thinner even if the temperature stays below zero?
- **e** you can see a cloud of mist coming out of your mouth when the weather is cold?

24 This exercise is about the words 'solidify' and 'freeze'.
Explain:
- **a** the similarity between the meanings of these words.
- **b** the difference between the meanings of these words.

25 If you hold an ice cube in your hand, the ice melts.
Describe what is happening to the water molecules then.

26 Which phase transition is involved:
- **a** when your clothes dry out again in the wind after a shower?
- **b** when water appears on the inside of the classroom windows on a cold day?
- **c** when you make ice cubes in the freezer compartment of the fridge?
- **d** when you thaw out the freezer compartment of the fridge?
- **e** when the mirror in the bathroom fogs up?
- **f** when the water in a birdbath slowly disappears?
- **g** when water appears on the outside of the glass of a cold soft drink?
- **h** when the washing on the line 'freezes dry' in the winter?
- **i** when ice crystals appear on deep-frozen products?
- **j** when you carefully allow potatoes in a pan to boil dry?

27 When Brian comes home and goes inside, the lenses of his glasses fog up straight away.
- **a** What can you say about the temperatures indoors and out?
- **b** Where do the water droplets come from that are misting up Brian's spectacle lenses?
- **c** Which phase transition is involved here?

28 The weather forecast issues a fog warning: "Fog may form throughout the country during the night. This may affect road traffic severely. During the morning, the fog will clear."
Which phase transition is responsible:
- **a** for the fog occurring?
- **b** for the fog clearing up?

Nova © Uitgeverij Malmberg

29 In the summer, the Sun may sometimes be shining again brightly immediately after a heavy shower of rain. In cases like that, a mist can appear above a road surface (figure 26).

- **a** People will then often say that "the road is steaming". But are you actually seeing steam? Explain.
- **b** Explain what is causing the mist. Tip: the mist is the result of two phase transitions occurring, one rapidly after the other.

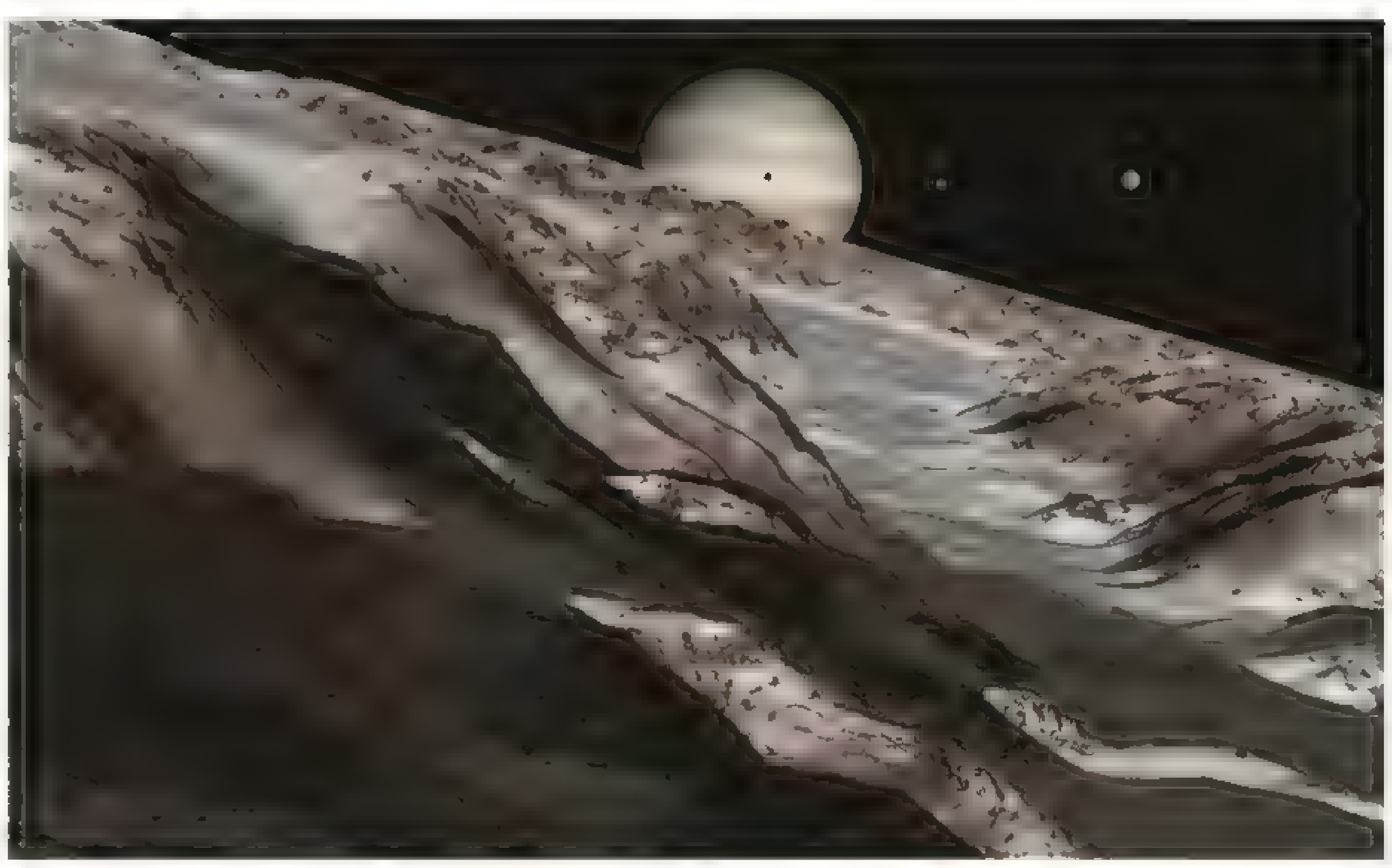
▲ **figure 26**
Bright sunlight after a heavy shower can make a road 'steam' like this.

***30** If you put a little bit of ether (a volatile liquid) on a watch glass, the ether evaporates quickly.

- **a** Only molecules with relatively high speeds are able to escape from the liquid.
  Why are molecules travelling at lower speeds unable to escape from the liquid?
- **b** What happens to the average speed of the molecules remaining behind in the liquid?
  - A The average speed becomes faster and faster.
  - B The average speed stays the same.
  - C The average speed becomes slower and slower.
- **c** What does that mean for the temperature of the remaining liquid?

***31** At very low temperatures, ice becomes extremely hard (figure 27).
Give an explanation of this using the particle model.

The largest moon of Jupiter (and indeed in the entire solar system) is called Ganymede. The surface consists primarily of ice. Because it is extremely cold on Ganymede (surface temperatures range from −183 to −113 °C), the ice is exceptionally hard – much harder that the ice you might come across on Earth.



▲ **figure 27**
A website about Ganymede; the picture is an artist's impression.

Plus Water: an exception

32 Refer to the graph in figure 24.

a Which liquid has the greater density: water at 0 °C or water at 2 °C? Explain your answer.

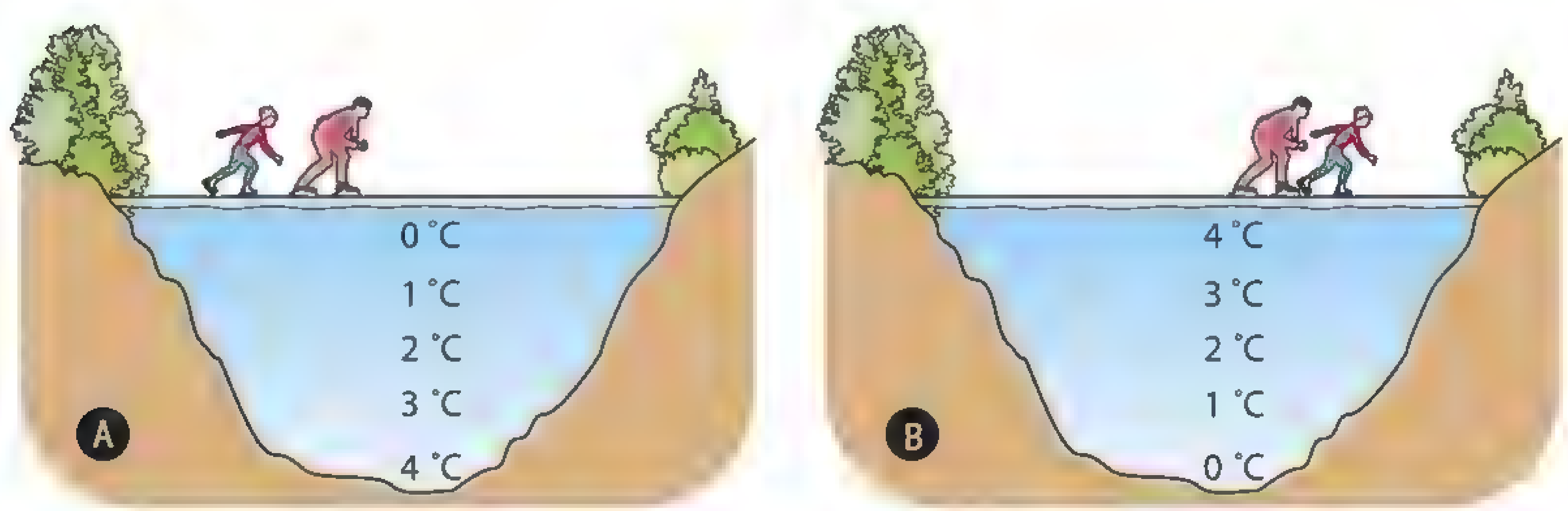
b There is another temperature at which water has the same density as at 0 °C.
What temperature is that?

33 If a water pipe freezes in the winter, it can burst.

a Explain why this can happen.

b You will only notice that the water pipe is broken when it starts to thaw. Why is that?

34 Figure 28 shows you two possible temperature distributions for the water in a pond during a period when it has been freezing for some time. There is a layer of ice on the water.
Explain which of the water temperature distributions is correct.



▶ figure 28
Which water temperature distribution is correct, A or B?

Nova © Uitgeverij Malmberg

4 Boiling point and melting point

▲ figure 29
When water is boiling, you can see bubbles of steam developing throughout the liquid.

The rainwater that falls during a shower disappears very quickly. Some of it is channelled away through the sewers, some is absorbed into the soil and some evaporates. The evaporation process is unspectacular. You don't notice anything at all, other than that the quantity of water slowly decreases. But water can also evaporate in a much more obvious way ...

The boiling point   Experiments 2 and 3

If you heat water, tiny air bubbles will appear after a little while. The air that is dissolved in the water is then reappearing. A couple of minutes later, bubbles of water vapour appear in the water. The temperature is then almost 100°C. These bubbles appear at the bottom and disappear again before reaching the water surface. This can then make a noise: a kettle of water coming to the boil may be said to be 'singing'.

When the temperature has reached 100 °C, the steam bubbles do reach the water surface. There they pop and the water vapour mixes with the air above the water. That is **boiling**: the water is now not only evaporating at the water surface, but throughout the liquid (figure 29).

If you keep on heating it, the water will keep boiling until it has all evaporated. The temperature of the water remains at 100 °C while it is boiling. This temperature is known as the **boiling point** of water (the word 'point' is used because it is a fixed point on the temperature scale). Almost every pure substance has its own characteristic boiling point. A few examples are given in table 2. The boiling point is an important property of a substance.

▼ **table 2** melting points and boiling points of various substances

substance	melting point (°C)	boiling point (°C)
alcohol	−114	78
aluminium	660	2467
butane	−138	−0.5
glycerol	20	290
gold	1064	2860
iron	1559	2800
mercury	−39	357
lead	328	1740
propane	−188	−42
nitrogen	−210	−196
water	0	100
oxygen	−219	−183

Melting point and freezing point

If you put an ice cube tray of water in the freezer compartment it takes a little while before ice is made. The temperature of the water in the mould must first drop to 0 °C. Only then will the water freeze. The temperature of the water remains at 0 °C until it is entirely frozen.

When you take the ice cubes out of the freezer compartment, they do not start to melt right away either. The temperature of the ice has to rise to 0 °C first. The first melted water will only appear after that temperature has been reached (figure 30).

▲ figure 30
An ice cube 1 minute, 5 minutes and 15 minutes after being taken out of the freezer compartment.

Melting ice is therefore at the same temperature as freezing water: 0 °C. This temperature is known as the **melting point** of ice and the **freezing point** of water. Almost every pure substance has its own characteristic melting point (or freezing point, as it is also known). A few examples are given in table 2.

Lowering the freezing point or melting point Experiment 4

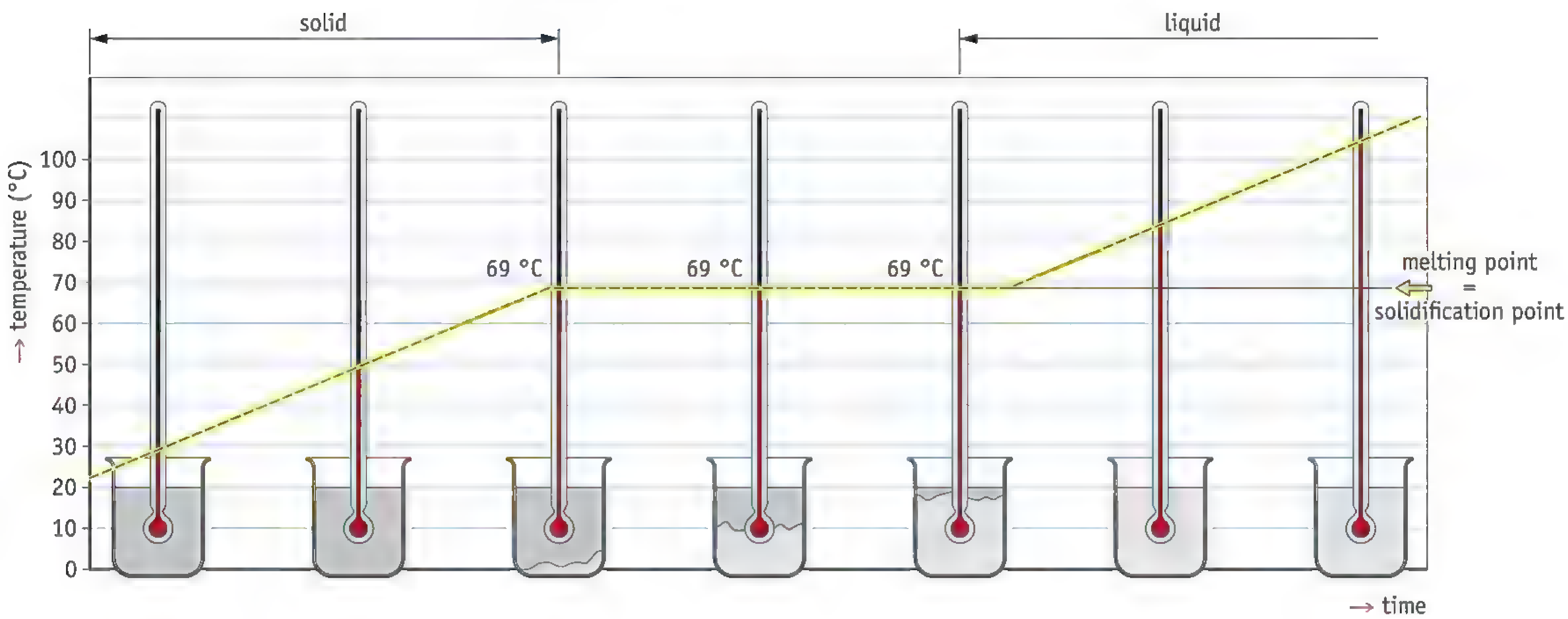
You can lower the freezing point of water by adding a suitable substance to the water. This is known as 'freezing point depression'. This is done with the coolant water in a car engine, for example. Antifreeze is added to it to prevent it from freezing during the winter. The more antifreeze is added, the lower the freezing point of the mixture becomes.

Salt has the same effect on the freezing point as antifreeze. It is used during the winter to get rid of snow and ice on the roads (figure 31). A mixture of ice and salt has a lower melting point than pure ice. Spreading salt can make snow or ice melt away, even at temperatures below zero. In practice, salting the roads is effective at temperatures down to –8 °C.

▶ figure 31
Spreading salt makes the snow on the road surface melt.

Melting and solidification diagrams

Figure 32 sketches out how the melting point of a solid substance can be determined. You heat the substance carefully and measure the temperature at regular intervals. In figure 32, this is being done for stearic acid. This is a substance that is used for a variety of purposes, including making candles (figure 33).



▲ figure 32
the melting diagram of stearic acid

When you heat solid stearic acid, the temperature first increases to 69 °C, the melting point of stearic acid. At that temperature, the stearic acid starts to melt. If you carry on heating, the temperature remains at 69 °C until all the stearic acid has melted. Only then does the temperature start increasing again. Figure 32 shows the way the temperature changes in a **melting diagram:** a graph showing the temperature against time.

If you let liquid stearic acid cool down, the temperature drops to 69 °C again: the solidification point of stearic acid. The temperature remains at 69 °C until the stearic acid has fully solidified. The temperature can then drop further. You can show the way the temperature changes in a **solidification diagram**, a graph showing the temperature against time.

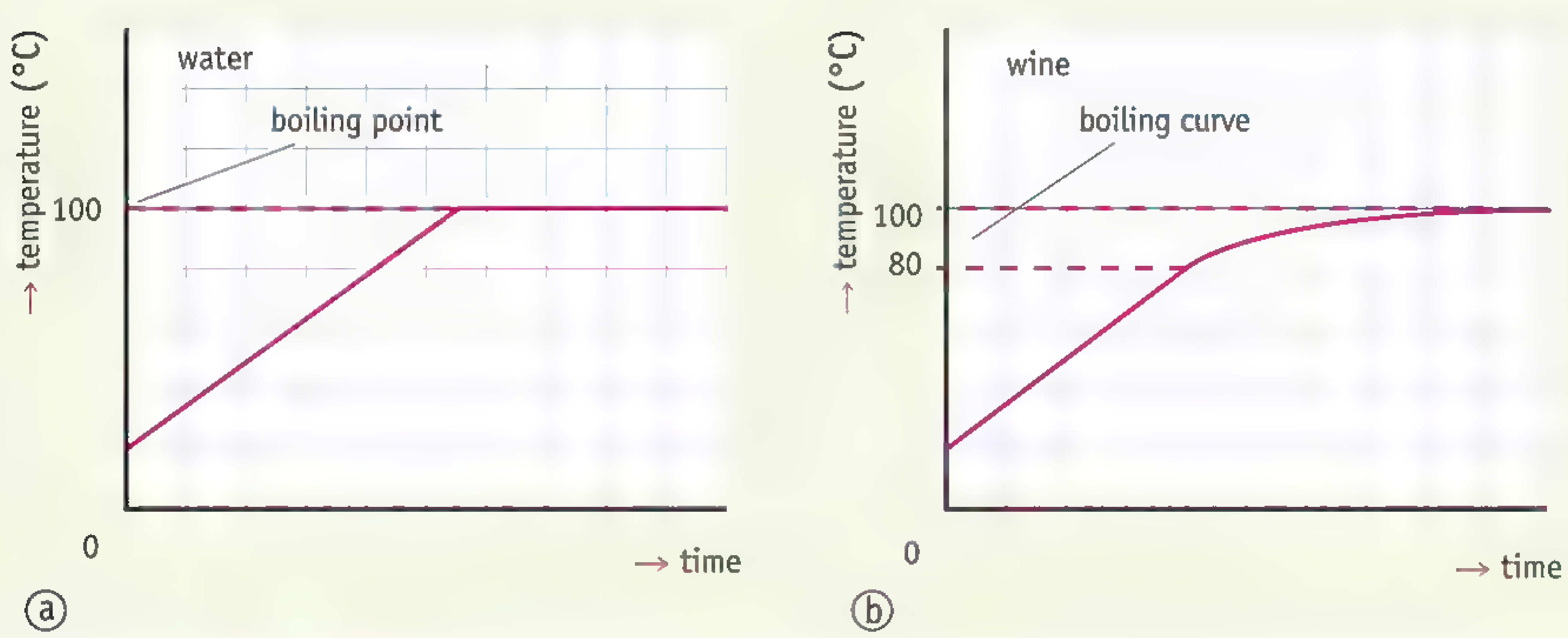
◀ figure 33
Candles consist largely of stearic acid.

Plus The boiling curve of a mixture

Wine is a mixture consisting mostly of water and alcohol. The proportion of other substances can be ignored in practice. A bottle of wine contains about 12 per cent alcohol by volume. That means that 100 mL of wine consists of about 12 mL alcohol and 88 mL water.

When you bring wine to the boil, you will notice that it starts to boil at about 80 °C. The temperature then increases slowly to 100 °C (figure 34b). Wine therefore does not have a fixed boiling point in the way that pure water (100 °C) or pure alcohol (78 °C) does. The temperature of the wine does not remain constant while it boils.

What applies for wine is also true for other mixtures of liquids. Mixtures such as these do not have a boiling point. Instead, they have a boiling curve. The **boiling curve** of wine goes from 80 to 100 °C.



▼ **figure 34**
Water has a boiling point (a), whereas wine has a boiling curve (b).

Exercises

35 Copy and complete:

a Melting ice has a temperature of ...... This temperature is known as the ...... of water or the ...... of ice.

b A mixture of ice and salt has a ...... melting point than pure ice.

c Boiling water has a temperature of ...... This temperature is called the ...... of water.

36 Compare the boiling of a kettle of water and the evaporation of a puddle of water.

a How does water change phase in these two situations?

b Explain *where* the phase transition takes place in each of these situations.

c How can you see that water is boiling and not 'simply' evaporating?

37 Explain what antifreeze is and what you do with it. Include the phrase 'freezing point' in your explanation.

38 Jez is cooking rice. When the water begins to boil, he turns the gas lower. The water then keeps simmering gently.
- **a** What is the temperature of the boiling water?
- **b** Will it take any longer for the rice to cook if you turn the gas down?
- **c** Why is it a good idea to turn the gas down?

39 You need worksheet 3-2 for this exercise.
Peter is heating a liquid. He records the temperature of the liquid every half minute. His observations are given in table 3.
- **a** See 'Skills 13' at the back of the book.
  Draw a graph of Peter's observations on the worksheet, with time on the horizontal axis and temperature on the vertical axis.
- **b** What is the boiling point of the liquid?
- **c** What liquid might it be?

▼ **table 3** Peter's measurement results

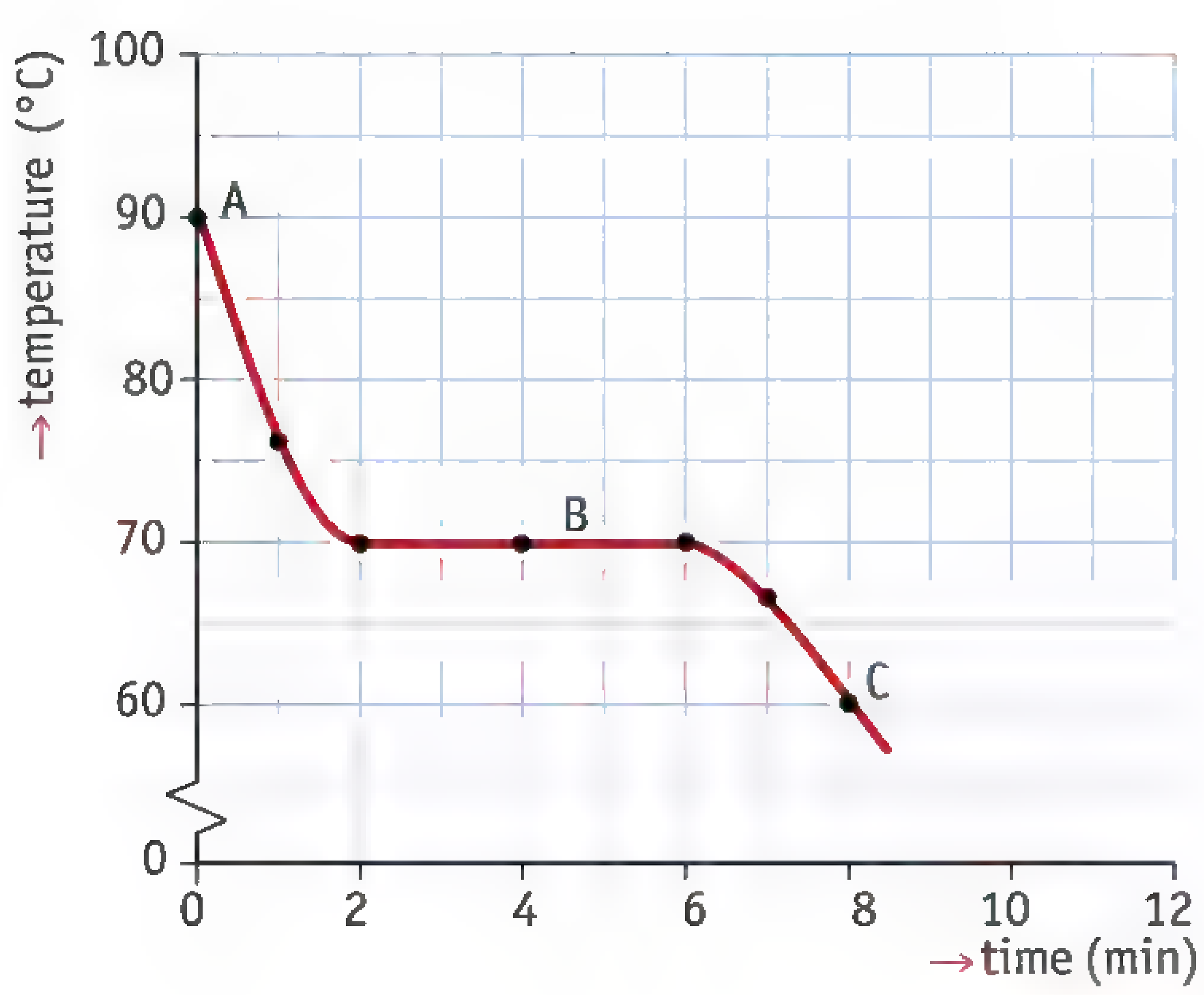
time (min)	temperature (°C)
0	20
0.5	33
1.0	46
1.5	58
2.0	68
2.5	75
3.0	77
3.5	78
4.0	78
4.5	78

40 Search the Internet for information about the metal gallium.
- **a** What does the metal gallium look like at room temperature?
- **b** What are the melting point and boiling point of this metal (in °C)?
- **c** What is unusual about the melting point and boiling point of gallium? Tip: compare the values you find with the melting points and boiling points of other metals.
- **c** You can buy teaspoons made of gallium in joke shops. What happens if you stir a cup of hot tea with one? Tip: have a look on YouTube.

41 In the winter, salt is sometimes spread on a frozen road surface. The layer of ice then melts.
Is the temperature of the meltwater then higher than, lower than or equal to zero degrees Celsius? Explain your answer.

42 Alice has melted a quantity of stearine. She then allows the stearine to cool slowly, taking temperature measurements every minute. After the experiment, she makes a graph of her observations (figure 35).
- **a** What is the name for the type of graph that Alice has made?
- **b** What phase is the stearine in at A? And at C?
- **c** During which part of the experiment are both liquid and solid stearine present?
- **d** What is the solidification point of the stearine?

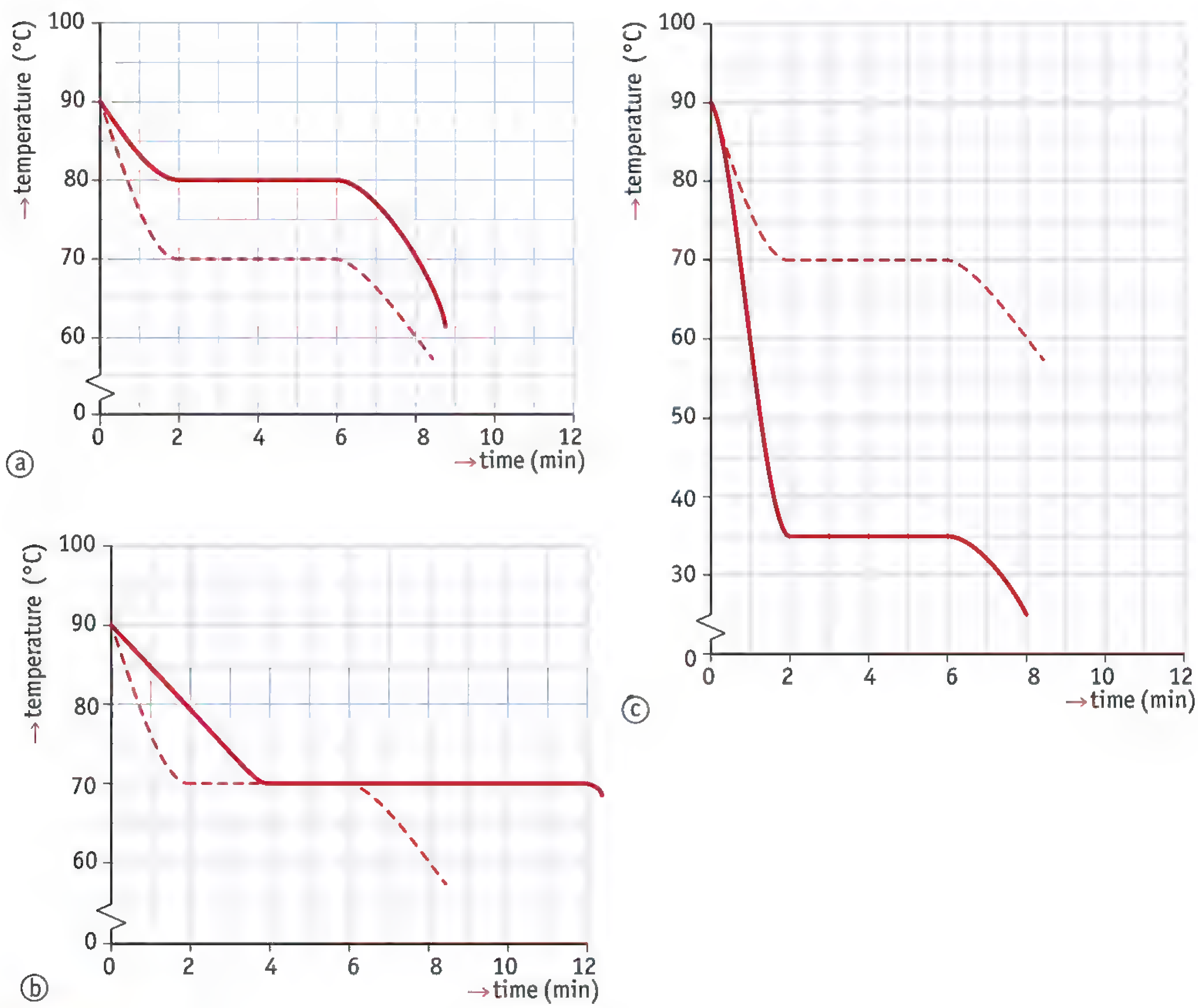
▼ **figure 35**
Alice's graph



43 Lakshmi does the same experiment as Alice, but uses twice as much stearine. She also makes a graph of her observations.

- **a** Which of the three graphs in figure 36 could be Lakshmi's? Assume that neither Lakshmi nor Alice made any mistakes in carrying out the experiment.
- **b** Explain your choice.

▼ figure 36
Which graph is correct?



***44** In a demonstration, liquid nitrogen is poured into a glass beaker from a Dewar flask (a kind of thermos). See figure 37.

- **a** How is it possible for the nitrogen to start boiling 'spontaneously'?
- **b** What is the temperature of the boiling nitrogen in the glass beaker?
- **c** What is the white mist around the glass beaker made of?
- **d** Ice appears on the glass beaker. Explain why this happens.

◀ figure 37
A demonstration with liquid nitrogen.

▲ figure 38
a can of white spirit

Plus The boiling curve of a mixture

45 The numbers 100/140 are written on a jerry-can of white spirits. These numbers represent the boiling curve of the white spirits (in °C). See figure 38.

- **a** The labelling on the can is actually incorrect. What should it really say?
- **b** If you heat white spirits, the liquid will begin to boil after a couple of minutes.
  What will a thermometer read if you hold it in the white spirit then?
- **c** What will the thermometer read when almost all the white spirit has evaporated?
- **d** Determining the boiling curve of white spirit is not difficult. However, this experiment is not one that is ever done at school.
  Give two reasons why this experiment is not allowed to be done at school (think them up yourself).

46 You need worksheet 3-3 for this exercise.
Rohan is melting a quantity of beeswax in a test tube. As it progresses, he measures the temperature. You can see his measurements in table 4.

- **a** Draw the melting diagram for this experiment on the worksheet.
- **b** How many minutes does it take before the beeswax starts to melt?
- **c** What is the temperature then?
- **d** After how many minutes has all the beeswax melted?
- **e** What is the temperature then?
- **f** Is beeswax a pure substance or a mixture? How can you see that?

▼ **table 4** Rohan's measurement results

time (min)	temperature (°C)
0	20
1	31
2	40
3	43
4	46
5	49
6	51
7	54
8	57
9	60
10	71
11	83

Experiments

Experiment 1 Calibrating a liquid thermometer 30 min

Introduction
A liquid thermometer has a reservoir and a capillary tube that has a scale marked along it in degrees Celsius (°C), which you can use to read off the temperature.

Aim
In this experiment, you are going to add a graduated scale to a thermometer.

Requirements
- masking tape
- glass beaker
- ice blocks
- an ungraduated thermometer
- an ordinary thermometer
- Bunsen burner
- tripod
- wire mesh
- matches/lighter

Doing the experiment and writing it up
Determining the zero point
- Stick a narrow strip of masking tape close to the capillary tube.
- Place the ice blocks in the glass beaker. Put the thermometer in it. The reservoir must be surrounded on all sides by the ice blocks (figure 39).
- Wait for two minutes. Then put a pencil mark on the masking tape showing where the alcohol level is.
- Remove the thermometer from the ice and write the number 0 next to the mark.

Determining the hundred point
- Fill the beaker one third full with water. Use the Bunsen burner to heat the water until it is boiling.
- Put the thermometer in the glass beaker. Leave the thermometer in the boiling water for one minute. Then make a pencil mark on the masking tape at the point the liquid has reached.
- Take the thermometer out of the water. Turn the burner off. Write the number 100 next to the mark that you have just made.

Calibration and measurement
- Add marks to subdivide the space between the 0 and 100 into ten equal parts. Put the numbers 10 to 90 next to the marks.
- Measure the temperature in the classroom using thermometer that you have just made a graduated scale for. Try to determine the temperature to an accuracy of one degree. Then measure the temperature in the classroom again, but this time with an ordinary thermometer.

1 What temperature does each of the thermometers give?

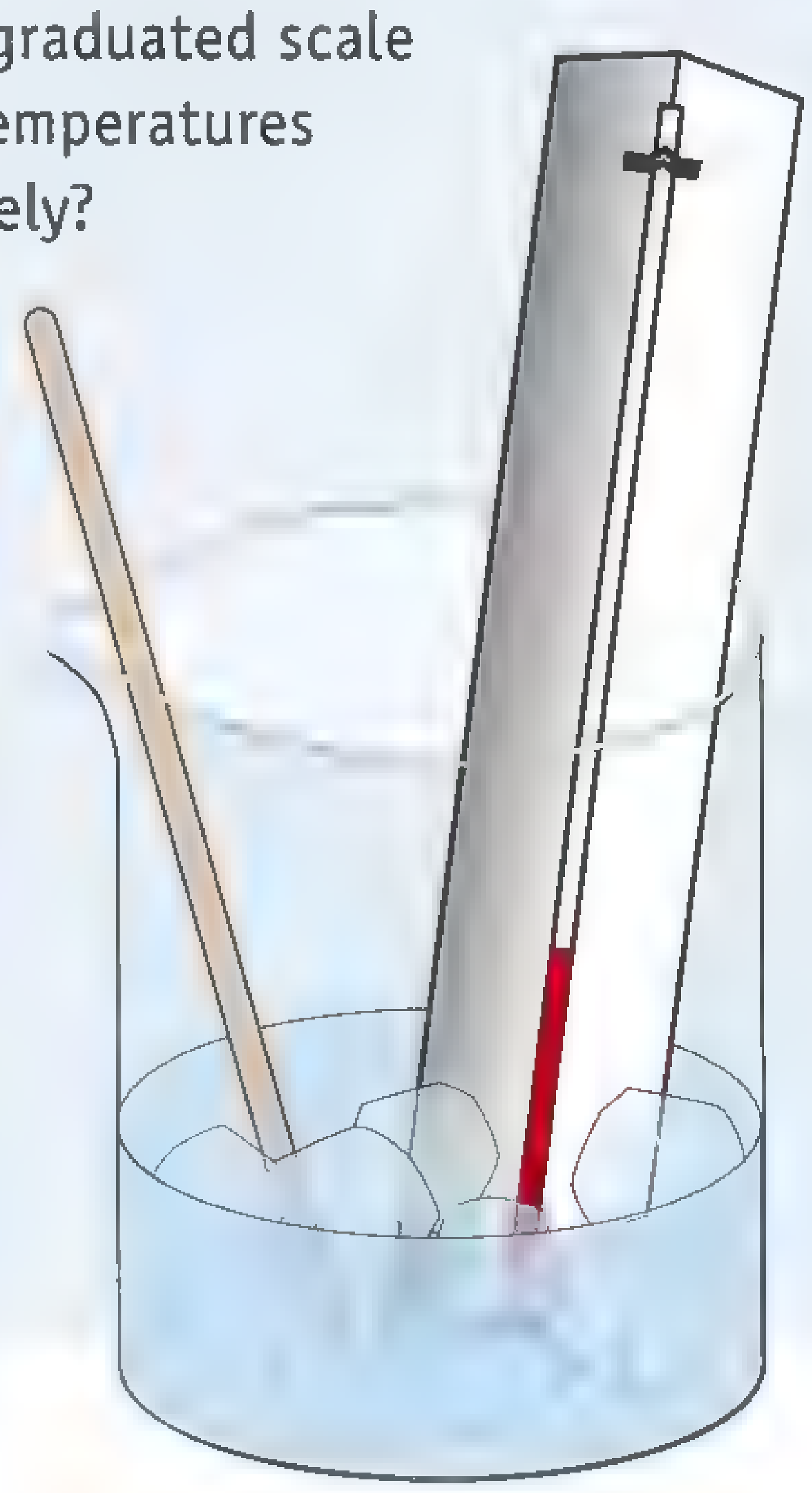
- Use both thermometers in the same way to measure the temperature of tap water immediately after it comes out of the tap.

2 What temperature does each of the thermometers give?

- Use both thermometers as well to measure temperature of your body. Hold the reservoir of each thermometer under your armpit for 30 seconds before reading the temperature.

3 What temperature does each of the thermometers give?

4 Can you use the thermometer that you have just added a graduated scale to for measuring temperatures reasonably accurately?



▶ **figure 39** the thermometer in ice water

Experiment 2 Boiling water 30 min

Introduction
When you heat a substance, the temperature of the substance increases. You see that for example when you boil water for a cup of tea.

Aim
In this experiment, you are going to investigate for yourself how the temperature changes.
The question you are studying is:
How does the temperature of water change when you bring the water to the boil?

Requirements
- glass beaker
- thermometer
- watch
- Bunsen burner
- tripod
- wire mesh
- matches/lighter
- worksheet 3-4

Doing the experiment and writing it up
Sharing the work
You do this experiment in pairs:
- Pupil 1 reads the temperature from the thermometer.
- Pupil 2 keeps track of the time and makes a note of the measurement results.

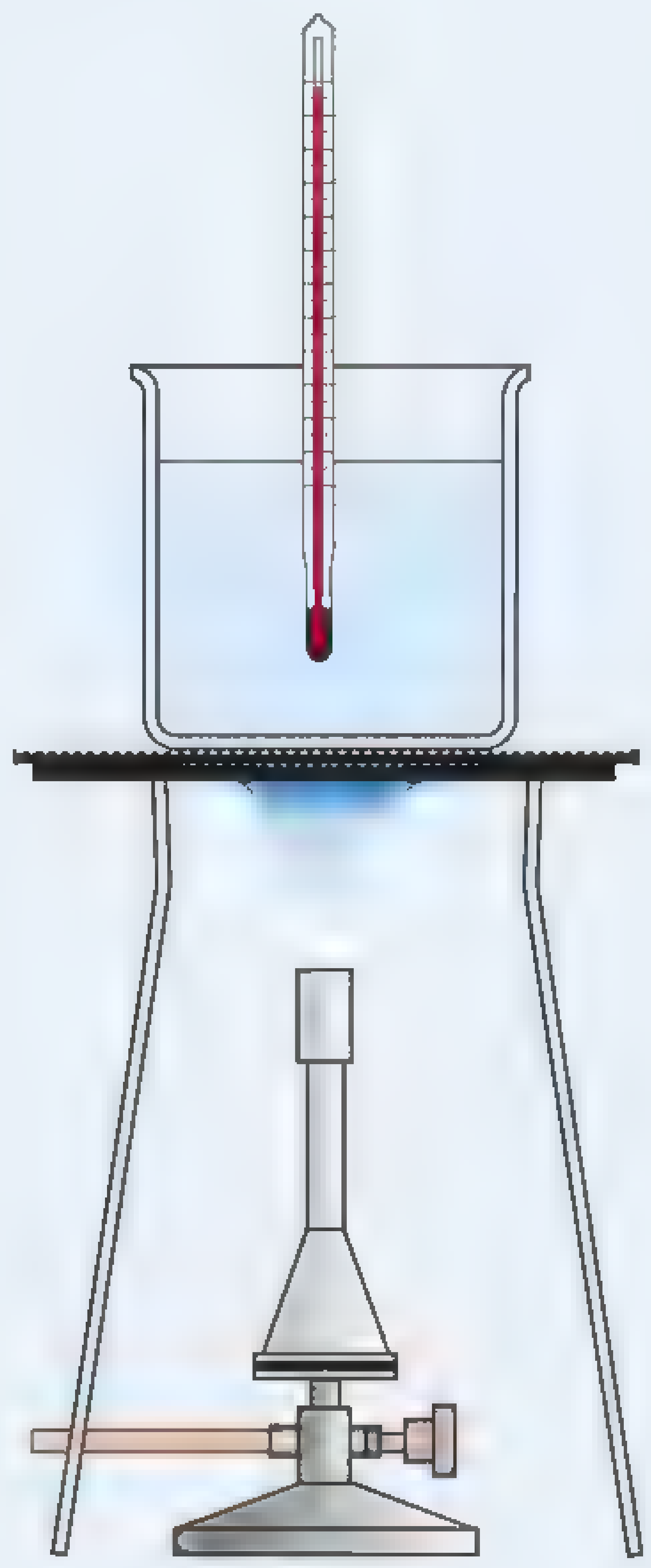
Preparation
- Put exactly 100 mL water in the glass beaker. Then set the experiment up as shown in figure 40.

1 Copy table 5 into your exercise book. Make a note in the table of the temperatures that you read off.

▼ **table 5** the measurement results for experiment 2

time (min)	temperature (°C)
0.0	
0.5	
1.0	
1.5	
etc.	

- Measure the initial temperature of the water.
- Light the Bunsen burner as you have been taught. Turn the gas control knob half open.
- Turn the air control knob far enough open that you get a flame that burns steadily (without making a lot of noise).
- Place the burner under the glass beaker on the tripod (figure 40).



▲ **figure 40**
the setup for experiment 2

- Read the thermometer off every thirty seconds. Keep the reservoir of the thermometer about a centimetre above the bottom of the beaker while making the measurement.
- At a given moment, the water will start boiling. Take four more temperature readings after that.
- Turn the burner off after the final measurement.

2 How could you see that the water was boiling?

- See how much water is left in the glass beaker.

3 Has any water disappeared from the beaker? If so, where did that water go?

Writing up

4 Take worksheet 3-4. Draw the graph for this experiment on it.
  a First, draw in your measurements as a series of points. See 'Skills 13' at the back of the book.
  b Then draw a single smooth line that passes through the measurement points as closely as possible. In other words, you should not simply join the dots together one by one with a ruler.

Experiment 3 The boiling point of alcohol 20 min

Introduction

Every pure substance has a boiling point. This is the temperature at which the substance boils. The boiling point is a property of the substance, so it is different for different substances. You can therefore identify a substance by its boiling point.

Aim

In this experiment, you are going to determine the boiling point of pure ethanol (= ordinary alcohol). Because ethanol is highly flammable, we will be doing the experiment in a special way.

Requirements

- glass beaker
- test tube with ethanol
- thermometer
- watch
- gas burner
- tripod
- wire mesh
- matches/lighter

Doing the experiment and writing it up

Preparation

- Put 200 mL water in the glass beaker.
- Heat the water with the burner. Use a blue flame that burns steadily (without making a lot of noise).
- Wait until the water boils. Then turn the burner off.
- Wait until your teacher has also turned off the main gas tap.

Measuring

- Place the thermometer in the ethanol in the test tube.
- Put the test tube with the ethanol into the hot water.
- Read off the temperature until there is no longer any change.

1 How does the temperature of the ethanol change during the experiment?
2 What do you see happening to the ethanol when the temperature is no longer increasing?
3 What is the boiling point of ethanol, according to this experiment?

- Smell the air close to the experimental setup and note the odour you observe there.

4 Try to describe the smell.
5 So what has happened to the ethanol?

Experiment 4 A cooling mixture 15 min

Introduction
When it is hot in the summer, lots of people enjoy eating a nice cold ice cream. If you want to make ice cream, you have to make sure that the ingredients get cold enough to freeze. There are special ice-making machines for this, but you can also use a cooling mixture.

Aim
This experiment will show you how you can use a mixture of salt and ice to generate temperatures of well below 0 °C.

Requirements
- glass beaker with 150 mL of finely crushed ice
- thermometer
- table salt
- spoon
- test tube
- orange squash
- stirring rod

Doing the experiment and writing it up
– Measure the temperature of the melting ice and make a note of it.

– Add three good spoonfuls of salt to the ice and stir the mixture for a few moments.

1 What do you see happening as you add the salt and stir it?

– Put the thermometer back in the ice/salt mixture straight away.

2 Make a note of the temperature every 15 seconds. Carry on doing this until the temperature is no longer changing.

– Put 1 mL of orange squash (about the thickness of your index finger) into the test tube and put it in the melting ice.

3 What happens to the orange squash? Why?

Homework task

4 Search the Internet for an ice cream recipe. Explain how you can use a chilling mixture to make ice cream.

Experiment 5 Evaporation and wind chill 15 min

Introduction
When you get out of the swimming pool in the summer, you will notice that the wind affects how you perceive the temperature. If there is no wind, it feels warmer than if there is a stiff breeze. This is because the wind makes the water on your skin evaporate more quickly.

Aim
For this experiment, you are going to be examining 'wind chill': the effect of evaporation on the subjective temperature (the temperature as you actually feel it).

Requirements
- dropper bottle of water
- dropper bottle of ethanol
- dropper bottle of nail varnish remover

Doing the experiment and writing it up
– Put a drop of water on the upper side of your forearm.
– Blow on it until the drop has evaporated.
– Put the same sized drop of ethanol on your arm.
– Blow on it until the drop has evaporated.
– Put the same sized drop of nail varnish remover on your arm.
– Blow on it until the drop has evaporated.

1 What did you feel while they were evaporating?
2 Which liquid evaporates fastest?
3 Which liquid feels coldest?
4 What link is there between the evaporation of liquids and the perceived temperature?

Experiment 6 Carrying out research: cooling by evaporation 30 min

Introduction
Imagine: a laboratory equipment manufacturer wants to develop a cooling device that will allow very low temperatures to be reached. The designer is asked to make use of the cooling effect of rapidly evaporating liquids. The question is then which liquid should be used to achieve the lowest temperatures. The research department is brought in for this problem. In this experiment, you are the scientist who has to carry out the research.

Aim
In this experiment you will be examining how far you can lower the temperature using three evaporating liquids: water, ethanol and nail varnish remover. You must compare the three liquids as fairly as possible.

Requirements
For this experiment, you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up
- Think how you can give the most reliable answer to the question. What are you going to measure, what items will you need for the experiment, how can you measure each liquid under exactly the same conditions?

1 Make a work plan for this research.

- The work plans will be discussed with the rest of the class at the next lesson. If necessary, you can make improvements to your own work plan after that.
- Then carry out the experiment.

2 Note down all the measurements, calculations and results in your exercise book.

- Your teacher will tell you whether or not you have to write up a report on this experiment.

Experiment 7 Producing a design: the rain gauge 90 min

Introduction
Imagine: your school is going to do a weather project in which the pupils will be gathering data about the weather themselves. One of the weather parameters is the amount of precipitation (rain, snow, hail, etc.) that has fallen over the previous 24 hours. The idea is that the pupils must make a reliable rain gauge for this themselves. You are given the task of designing such a meter.

Aim
In this experiment you will be designing, making and calibrating a rain gauge. Your prototype must meet the following design requirements:

Design requirements
- The rain gauge must be made of materials that are cheap or cost nothing. You can find ideas for this on the Internet.
- The graduated scale must show the number of millimetres of rain that have fallen since the last measurement. (That is how deep the water would be if the rain did not run off, evaporate or sink into the soil.)
- The rain gauge must 'multiply' the rise in the water level by a factor of at least 5: if 1 mm rain falls, the level of the water in the rain gauge must rise by at least 5 mm.
- The rain gauge must easily be 'zeroed' again after each measurement.
- The rain gauge must be stable and sturdily constructed. It must be possible to make measurements with it without difficulty for at least two weeks, even in bad weather.
- The graduated scale on the gauge must be calibrated: you must have checked whether the markings and numbers have been applied correctly.

Requirements
For this experiment, you have to think up for yourself what equipment you will need. Discuss it if necessary with your teacher.

Doing the experiment and writing it up
- Think how you can carry out the experiment. What components will your gauge contain, what items do you need, how can you test whether the graduated scale is correct?

1 Make a work plan for this experiment.

- The work plans will be discussed with the rest of the class in the next lesson. If necessary, you can make improvements to your own work plan after that.
- Construct the rain gauge and calibrate it carefully.

2 Make a test report that includes:
  - **a** a clear diagram showing how the rain gauge is constructed.
  - **b** the test you have carried out and the corresponding results.
  - **c** any changes that you have made to the design.

Nova © Uitgeverij Malmberg

Test Yourself

You can also do questions 1 to 16 on the computer.

1 Five types of precipitation are listed below:
dew – hail – rain – frost – snow
- **a** In which types of precipitation is the water liquid?
- **b** In which types of precipitation is the water solid?

2 Wayne says: "Mist is made up of water droplets."
Joy says: "Mist is made of water vapour."
Who is right?
- A They are both right.
- B Neither of them is right.
- C Only Wayne is right.
- D Only Joy is right.

3 Josh breathes on the window: the window fogs over.
What is the term for the phase transition:
- **a** that creates a moist spot on the window?
- **b** that makes this moist spot disappear again a little later?

4 Snowflakes are made up of ice crystals. Two statements about the molecules in such a crystal are given below.
- I The molecules all have their own base positions.
- II The molecules do not move at all: they are stationary.

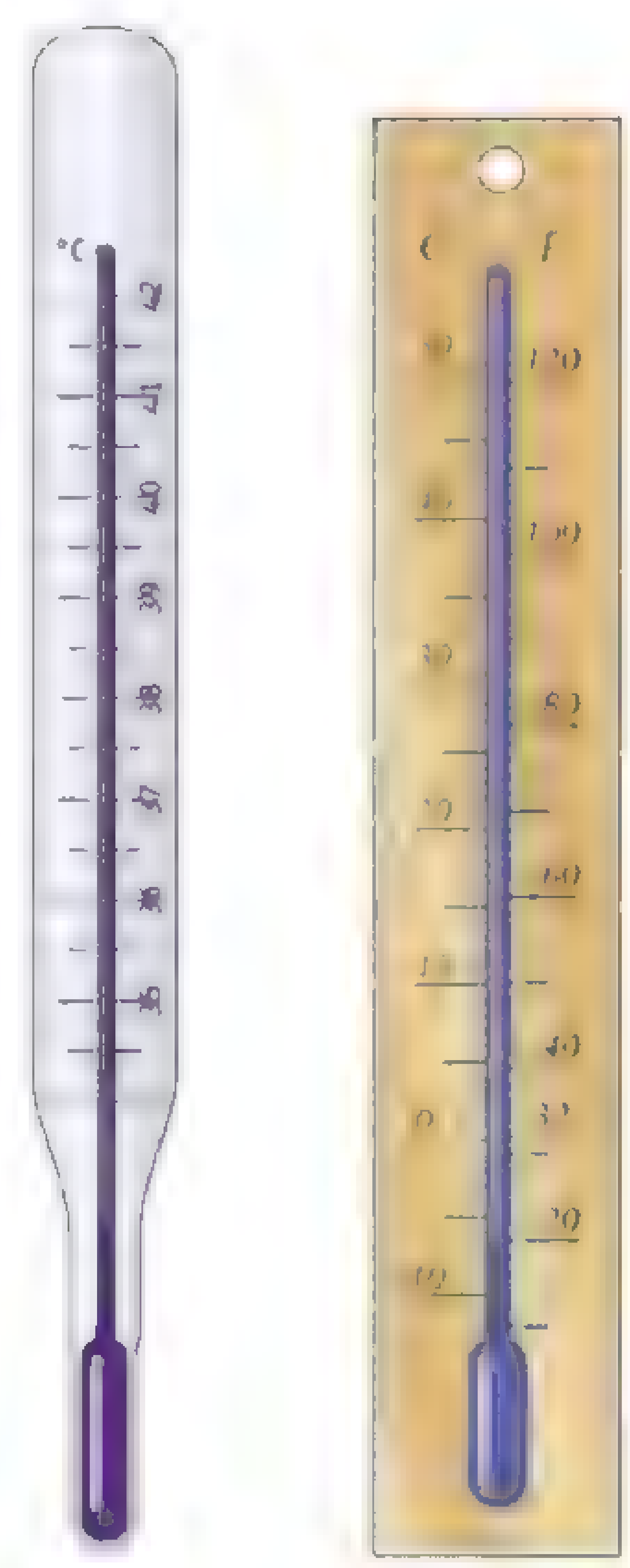
Which of these statements are correct?
- A neither of them
- B only I
- C only II
- D both I and II

5 Jack has two liquid thermometers. Thermometer A has the same dimensions as thermometer B. The liquid in A expands more per degree than the liquid in thermometer B.
Which thermometer lets you read the temperature more accurately?

6 Kieran has marked the zero point (0 °C) and the hundred point (100 °C) on an ungraduated thermometer. The two marks are 12 cm apart. How many centimetres below the mark for 0 °C should the mark for –20 °C be placed?

7 Continuation of question 6.
When Kieran puts the thermometer he has calibrated into water at an unknown temperature, the alcohol rises to 5.4 cm above zero degrees. Calculate the temperature the water.

8 Figure 41 shows two thermometers.
- **a** Which thermometer has the greater measurement range?
- **b** Which thermometer measures the temperature more accurately?



▲ figure 41
a clinical thermometer and a weather thermometer

9 Phase transitions play an important role in the weather.
In which phase transition can you see:
- **a** (liquid) water disappearing 'into nothing'?
- **b** ice crystals appearing 'out of nothing'?

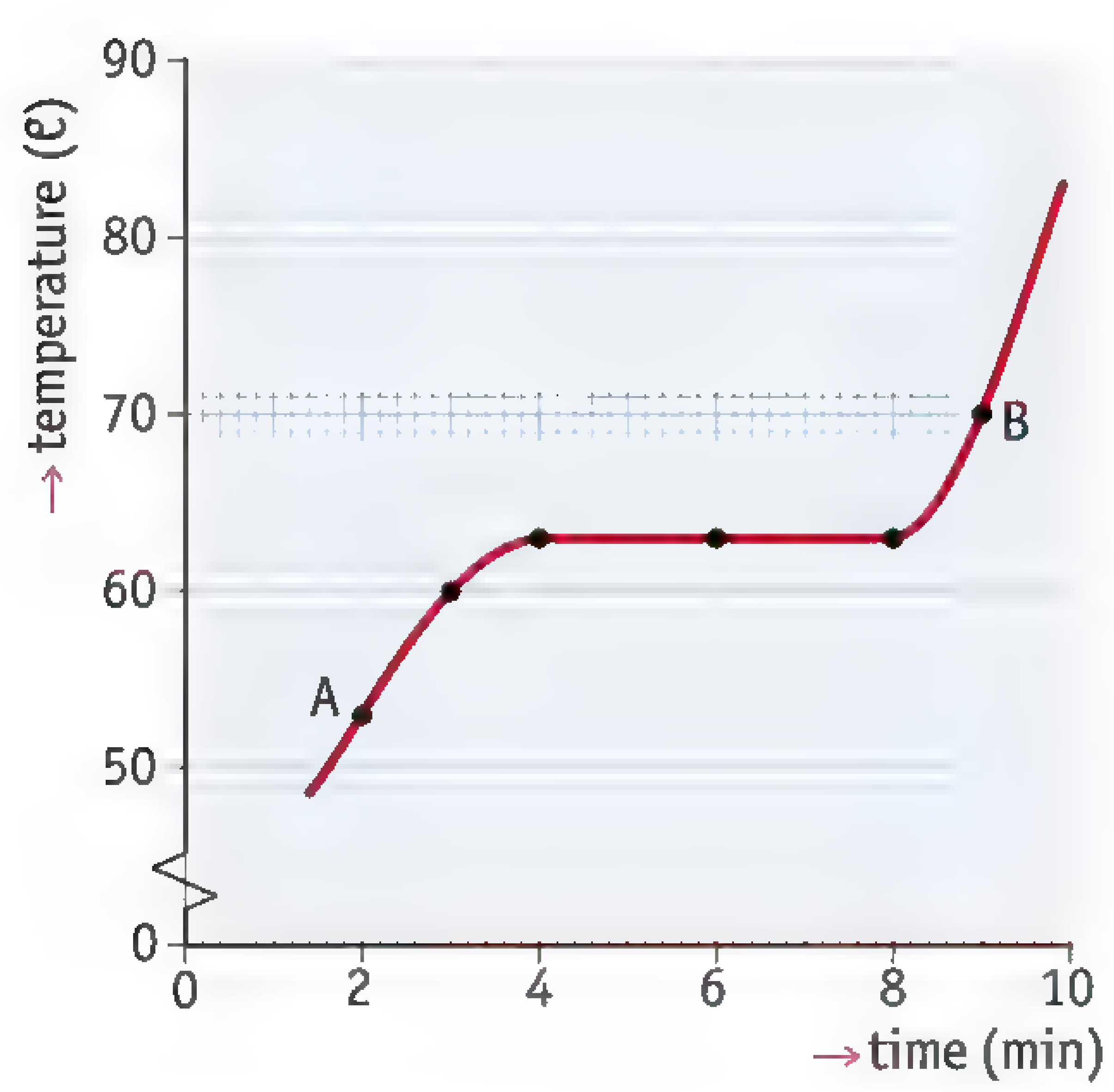
10 Read the weather report in figure 42.
- **a** Which phase transition causes cumulus clouds to be created?
- **b** Which phase transition causes the cloud cover to 'dissolve' again?
- **c** Why is it that ground mists can appear on clear summer nights in particular?

> The day will start with a clear blue sky. The first cumulus clouds will appear during the course of the morning. There will be sunny and cloudy periods in the afternoon, with temperatures of 22 to 23 °C. The clouds will have gone again by the evening. The night will be clear and localised patches of ground mist may occur.

▲ **figure 42**
a weather report

11 Drew closes the air control ring of his Bunsen burner. Then he lights the burner.
What kind of flame will the burner have now?
- A a blue, clearly visible flame
- B a blue, poorly visible flame
- C a yellow, clearly visible flame
- D a yellow, poorly visible flame

12 Lucy has done an experiment with palmitic acid (one of the components of candle wax). You can see the diagram of her experiment in figure 43.



▲ **figure 43**
Lucy's experiment

- **a** What is the name for the type of diagram that Lucy has made?
- **b** What phase is the palmitic acid in area A?
- **c** What phase is the palmitic acid in area B?
- **d** What is the solidification point of palmitic acid?
- **e** What is the melting point of palmitic acid?

13 Seawater is saline: a litre of seawater contains about 35 grams of salt. The water in a canal or lake is fresh: it contains no salt (or almost none). Which is correct?
- A Seawater freezes at a lower temperature than fresh water.
- B Seawater freezes at the same temperature as fresh water.
- C Seawater freezes at a higher temperature than fresh water.

14 Table 2 on page 72 lists twelve substances. Peter has a bottle containing one of these substances. At room temperature (20 °C), the substance is a syrupy liquid. When Peter leaves the bottle in the refrigerator, the substance solidifies.
Which of the substances in table 2 could it be?

15 State whether each of the following statements is true (T) or false (F).
- **a** The molecules in a solid substance each have their own base position.
- **b** The molecules in a solid substance cannot move in any way at all.
- **c** The molecules in a liquid keep as close together as possible.
- **d** When the temperature increases, the molecules attract each other more strongly.
- **e** The average distance between the molecules is greatest in a gas.

16 Water expands when it is heated.
Why does the water expand?
- A because the water molecules get bigger
- B because more and more water molecules are being added
- C because there is more space between the molecules

17 If you put your hand in a plastic bag and then tape the bag tight around your wrist, you will see water appear on the inside of the bag after a little while.
- **a** Which phase transition is involved here?
- **b** What presumably comes out through your skin?

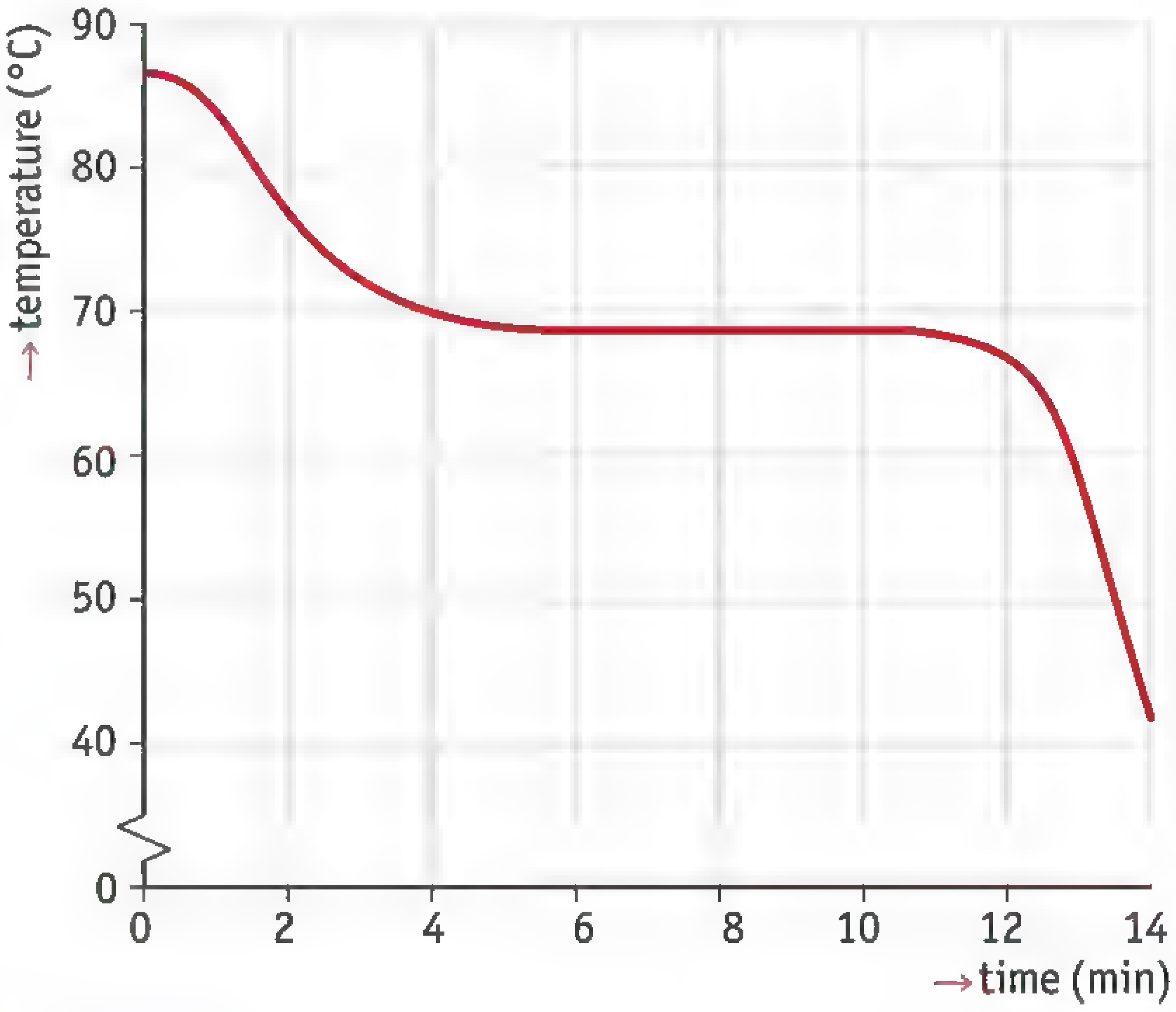
18 Around 1900, all trains were pulled by steam locomotives such as the one in the photo in figure 44.
- **a** Steam is hot water vapour.
Can you see steam? Explain.
- **b** What is the white plume that is coming out of the locomotive's stack made up of?
- **c** Which phase transition creates that white plume?

▲ figure 44
a steam train

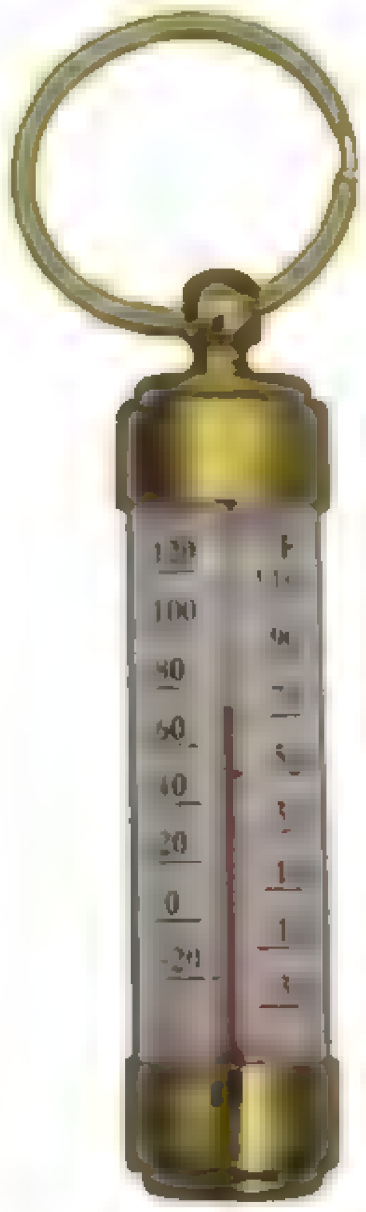
19 A website is offering a very small travel thermometer (figure 45).
- **a** Explain the design criteria that a travel thermometer such as this must comply with.
- **b** Compare a travel thermometer such as this one to a normal weather thermometer.
What can you say (in comparative terms) about:
  - the dimensions of the reservoir
  - the dimensions of the capillary tube
  - the measurement range
  - the accuracy

  of the two thermometers?
- **c** State two reasons why a small liquid thermometer such as this one may be an amusing thing to have, but is not a good choice from a practical point of view.

20 Mahmud has done an experiment with an unknown substance. First he melted the substance. Then he allowed the substance to cool again while he monitored the temperature using a computer. When it was finished, Mahmud got the computer to draw a diagram of the experimental results. See figure 46.
- **a** Is figure 46 a melting diagram or a solidification diagram?
- **b** How long did the experiment take (from the start of the measurements)?
- **c** What is the melting point/solidification point of the substance?
- **d** What substance might it be?



▲ figure 46
Mahmud's experiment

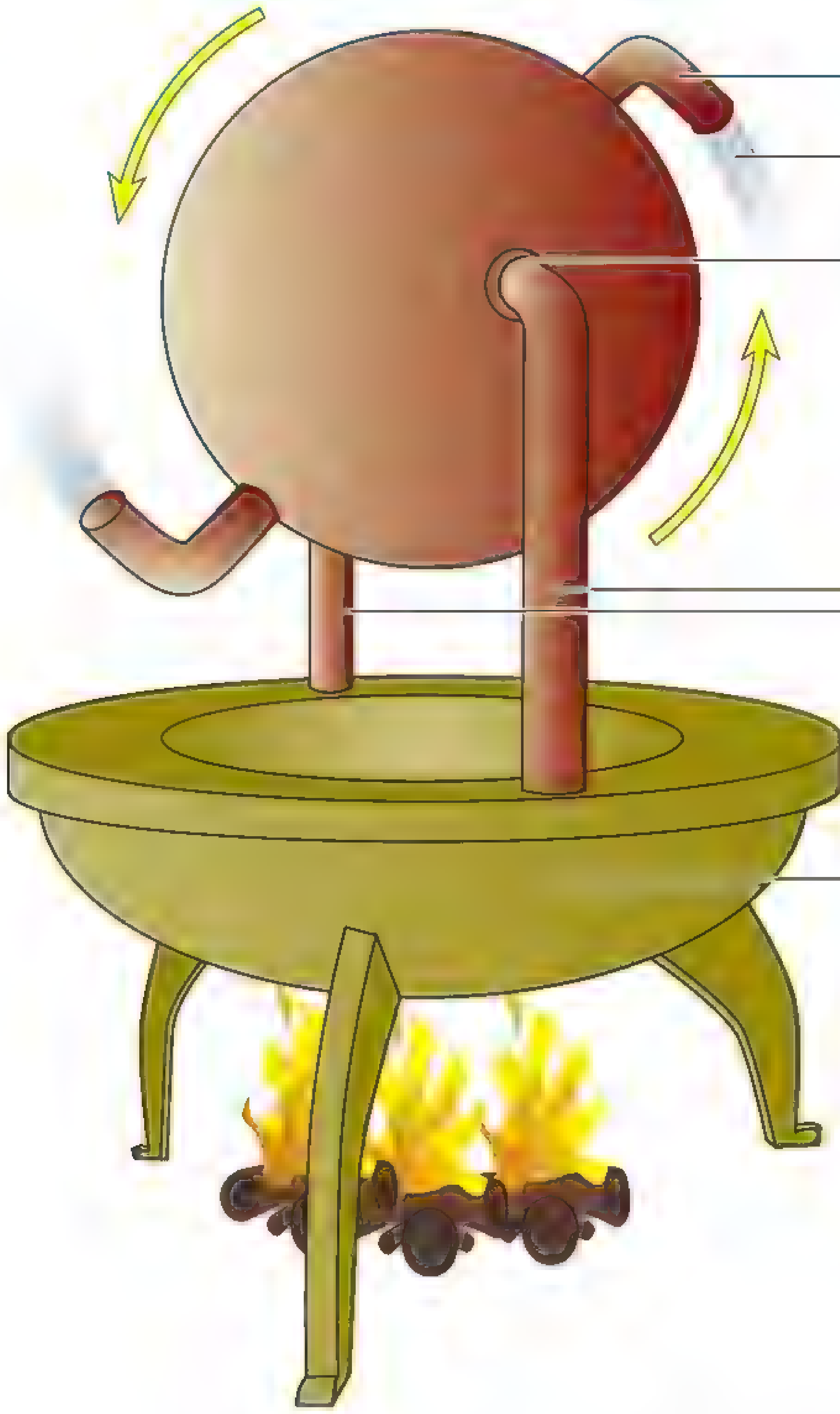


▲ figure 45
a miniature weather thermometer

Nova © Uitgeverij Malmberg

The explosive power of steam

First you hear the water bubbling and then the hiss of escaping steam. Then the ground under your feet starts to shake. Suddenly, a column of steam and boiling water fifty metres high shoots up out of the ground. While the clouds of mist float away on the wind, the eruption continues unabated for nine or ten minutes. Then the geyser stops again, almost as suddenly as it started. If you are lucky, there will be another show in eight hours' time or so.



The eruption of a large geyser is an impressive piece of theatre. The power that forces the jet of water upwards is massive. That power comes from superheated steam that has been formed deep under the volcanic soil (several kilometres down). A geyser occurs when the subterranean structure means that the steam cannot easily escape from the ground. The pressure keeps building up until it can no longer be contained. The steam then escapes explosively, with a force that blows tons of water into the air.

A 2000-year-old steam turbine

The fact that steam can exert a force was already known 2000 years ago. That was when Hero of Alexandria, a Greek scientist and inventor, built the world's first steam turbine. It was a primitive machine – to us it looks more like a toy than a serious piece of apparatus – but the thinking behind it was correct. A modern steam turbine works on the same principles.

The drawing above shows you how Hero's invention worked. Water was heated in a steam kettle. The steam that this created was passed through two hollow pipes and into a rotatable ball. The steam could escape from there through two bent nozzles. The force that this exerted was enough to get the ball spinning at quite a speed.

Hero's *aeolipile* (the name he gave to his invention) could spin for hours using just a few litres of water. This is because a small amount of water can generate a vast quantity of steam. If steam is allowed to expand without restriction, one litre of water can generate no less than 1600 litres of steam. Hero's *aeolipile* does not manage that, because the steam is able to escape from the device through two narrow openings. Even so, one litre of water is all you need here to create hundreds of litres of steam.

Trapping steam

If you boil water in a saucepan, the steam can escape in lots of directions. The steam does not have to push hard to create more space for itself. This creates a vast amount of steam, but no large forces. You see the same in volcanic areas where the steam can escape easily from the soil. This creates hot springs that bubble away and emit clouds of mist all the time, but no geysers that suddenly burst forcefully into life.

To make steam exert a force, you have to enclose it in a small space, such as the boiler of Hero's

aeolipile. When the water in the kettle boils, increasing amounts of steam are generated that cannot immediately escape. The pressure in the boiler and the ball therefore builds up a lot – and that is exactly what is needed to make the steam escape forcefully through the small jet nozzles.

Steam under high pressure is extremely suitable for making objects move. There is nowhere that demonstrates this better than a modern electricity generating station. Steam boilers forty metres tall produce steam for a series of turbines in the machine hall. The turbines are made to rotate by the extremely hot steam, which blows against the turbine blades – in the same way as the wind makes windmills go round, but this is many times more powerful. In turn, the turbines power the generators that provide electrical energy for hundreds of thousands of people.

Steam explosions

The power of steam can also be dangerous. A boiler or pipe that contains high-pressure steam can suddenly break because of a construction error or through age or poor maintenance. The steam then flows out with an irresistible force, blowing aside everything in its path. People can be injured not only by the hot steam but also by the debris flying around.

On 18 July 2007, an underground steam pipe under a busy crossroads in New York exploded. The steam blew water and mud more than 100 metres into the air. The Chrysler Building, which is 319 metres tall, was completely engulfed in the white mist clouds. The mists only disappeared after two hours, revealing a crater 10 metres across and 4 metres deep. The cause: a weak spot in an eighty-year-old steam pipe.

The explosive power of steam is also the reason why you must NEVER attempt to put out a chip pan fire with water. The combination of water plus hot burning fat is extremely dangerous. When the water comes into contact with the molten fat, it will turn into steam incredibly quickly. The steam explosion that this causes will then expel burning fat in all directions, creating a large fireball that will set everything around it alight.

Careful... steam!

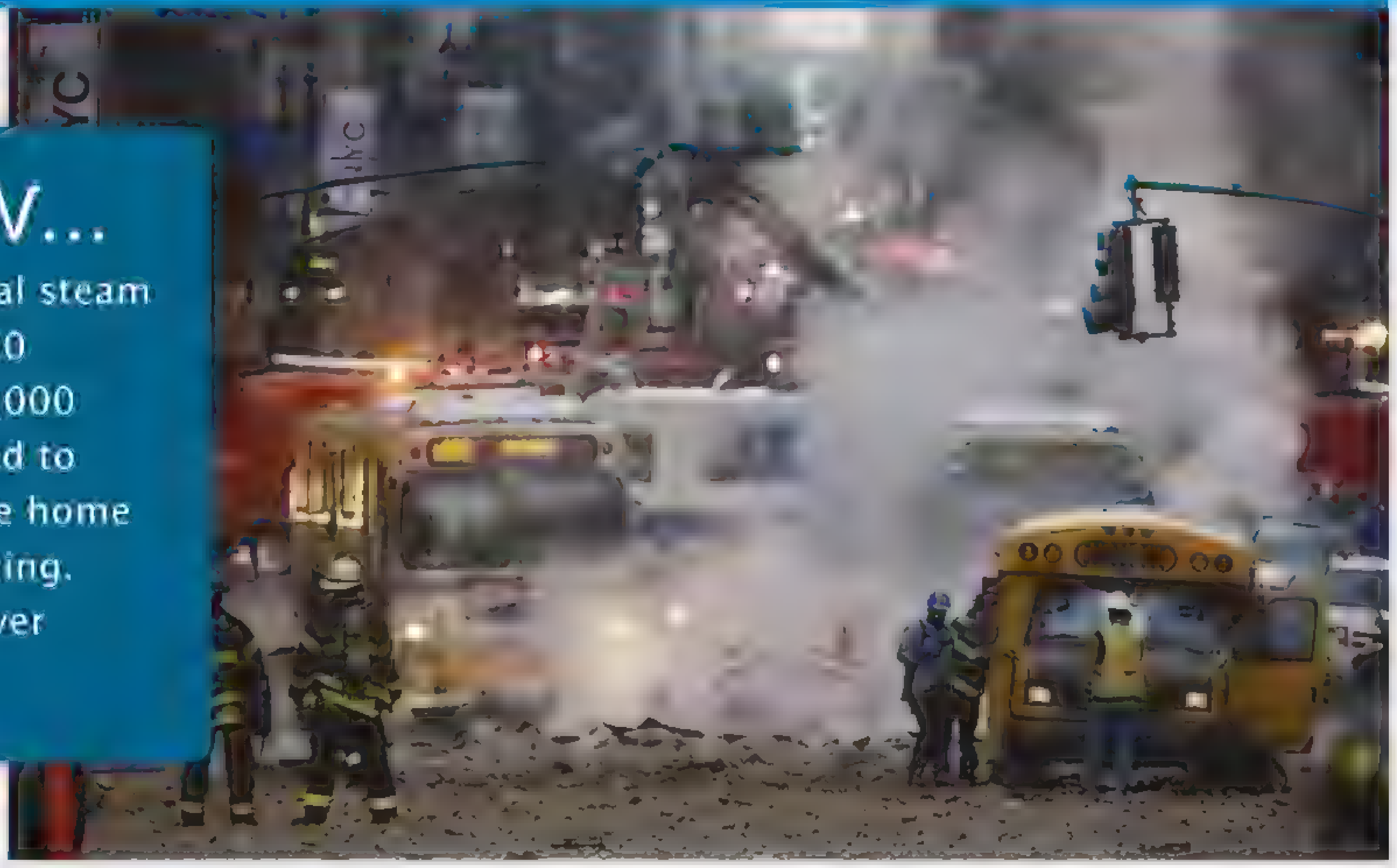
Steam boilers are designed carefully so that they can withstand the enormous forces produced by the steam. The designers also build in a safety margin, so even if the pressure does go above the maximum value allowed, you will not immediately have wreckage flying about your ears. There are all kinds of safety features as well. If the pressure in the boiler rises too far, safety valves will open immediately. This allows the steam to escape, so that the pressure in the boiler starts to drop. You will then see a big cloud of mist outside the boiler, as the hot steam condenses in the cold outside air.

Less attention was paid to safety at the start of the steam age, which is about 200 years ago now. But so many accidents occurred that this situation soon changed. The Steam Act came into force in the Netherlands in 1824. This contained numerous regulations that were intended to improve safety. People back then may have found all the regulations to be annoying at times, but safety did improve enormously as a result.

Old-fashioned steam engines are now virtually a thing of the past, but steam turbines are still very

Did you know...

New York has the largest commercial steam network in the world, with about 160 kilometres of pipes. More than 100,000 companies and homes are connected to the system. The key applications are home heating, hot water and air conditioning. Some of the steam pipes are now over 100 years old.

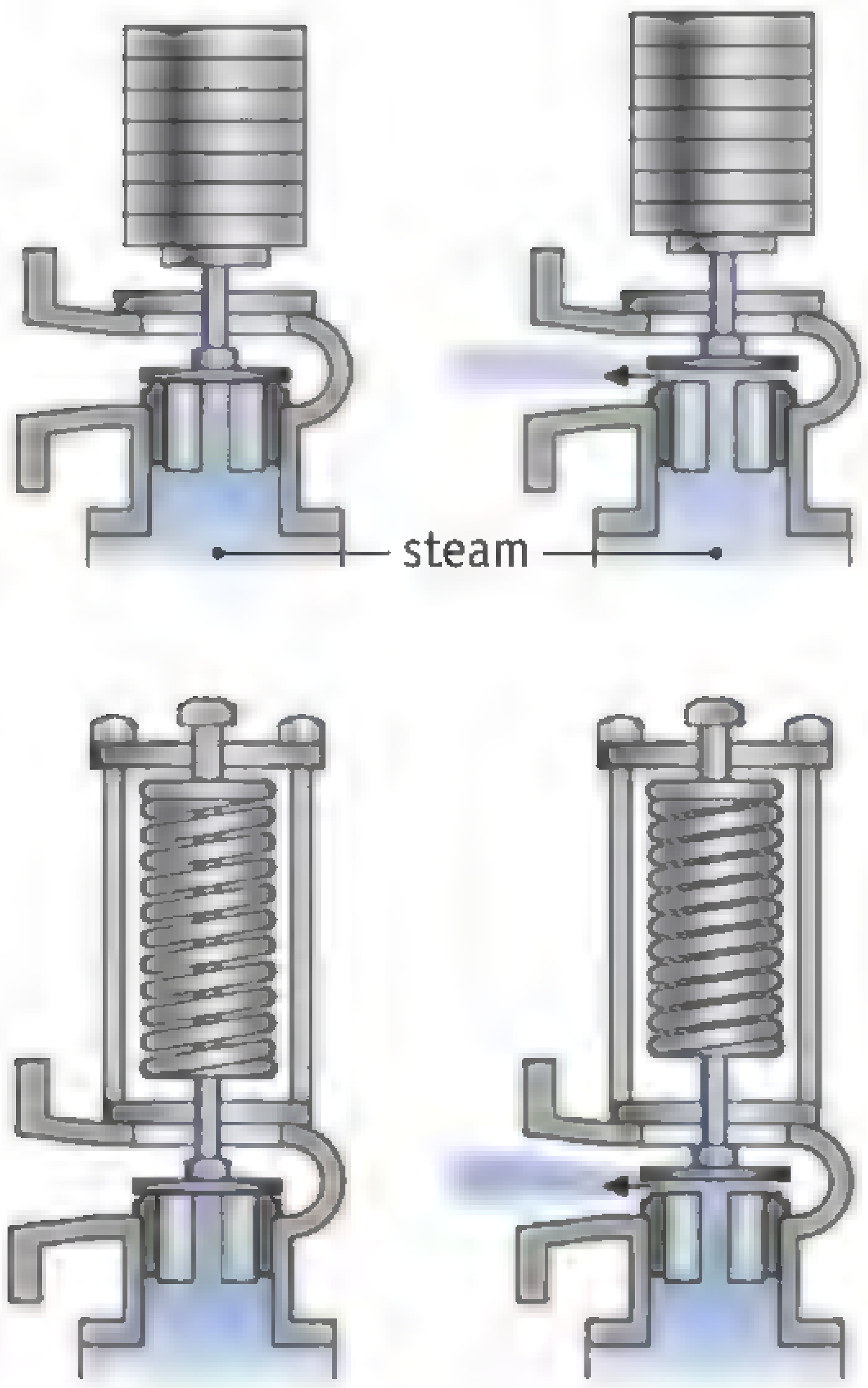


much going strong. They generate 80% of all the electrical energy that is consumed worldwide. Even a nuclear power plant cannot manage without steam turbines for converting heat into motion. Electricity has therefore not made steam redundant, but has instead only moved it... into the power station. So if you think about it carefully, you will see that even your smart phone and laptop are powered indirectly by steam.

New York hit by a steam explosion

NEW YORK (ANP) – A large explosion in the middle of New York rocked the American city during the evening rush-hour. The authorities say that an underground steam pipe blew up beneath one of the streets in central Manhattan. More than twenty people were injured. The steam pipe has now been depressurised. The damage is extensive.

De Volkskrant, 19 July 2007



Exercises

1 Explain why:
   - a geysers do not occur in areas where the ground is easily permeable for water and steam.
   - b the pressure in the kettle and ball of Hero's *aeolipile* increases when the water in the kettle starts to boil.
   - c you are taking a huge risk if you try to put out a chip pan fire with water.

2 Big clouds of white 'mist' are always produced when there is a steam explosion.
   - a What substance are these mist clouds made of? What phase is the substance in?
   - b The media talk about 'steam clouds' and 'clouds of water vapour'. Why are these terms rather inaccurate, from a scientific point of view?
   - c A newspaper report states, "The steam clouds dissolved again quickly."
     Translate this sentence from everyday or media language into scientific language.

3 Have a look at the two safety valves that are drawn here.
   Explain:
   - a how the safety valve above works.
   - b how the safety valve below works.

Nova © Uitgeverij Malmberg

Nova © Uitgeverij Malmberg

4
Air

Air for life

A paraglider can float for hours in the thin air high above the Earth. He can see people down below doing all kinds of things. Their lives are lived at the bottom of a sea of air (as is the life of the paraglider pilot when he isn't flying).

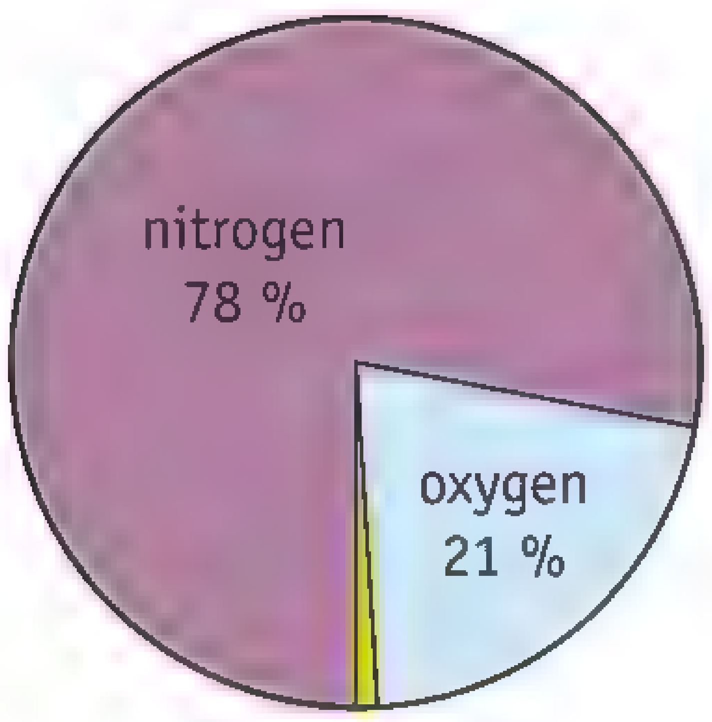
1 Air: a mixture of gases

Air is transparent and does not have any smell or taste, so you don't often bother to think about the fact that air is all around you. Nevertheless, you cannot live without air. You might manage a week without food or a day without water, if you had to. But you would not last more than a few minutes without air.

The composition of air

Experiment 1

Air is a mixture of various gases (figure 1). The most important components are **nitrogen** and **oxygen**. Air also contains small amounts of other gases, such as argon and **carbon dioxide**. It also contains water vapour, although the amount of water vapour per cubic metre can vary a lot.



▲ figure 1
the composition of air

Nitrogen

Air consists of 78% nitrogen (N_2). Your body does not need this gas. You breathe it in and out without anything happening to it in your lungs. Some foods, such as cakes and potato crisps, are packaged in 100% nitrogen, because they stay fresh for longer in this 'protective atmosphere' than they would in normal air.

Oxygen

Air consists of about 21% oxygen (O_2). People and animals need this gas to live. Breathing is how your body is supplied with the oxygen it needs. In your lungs, oxygen is absorbed into your blood from the air that you inhaled. The blood then transports the oxygen to every part of your body.

Carbon dioxide

On average, air only contains 0.03% carbon dioxide (CO_2). Even so, this gas is just as indispensable as oxygen for life on Earth. Plants need it in order to be able to grow. Carbon dioxide is also a component of all sorts of drinks, from cola to champagne. The 'fizz' in all these drinks comes from small bubbles of carbon dioxide.

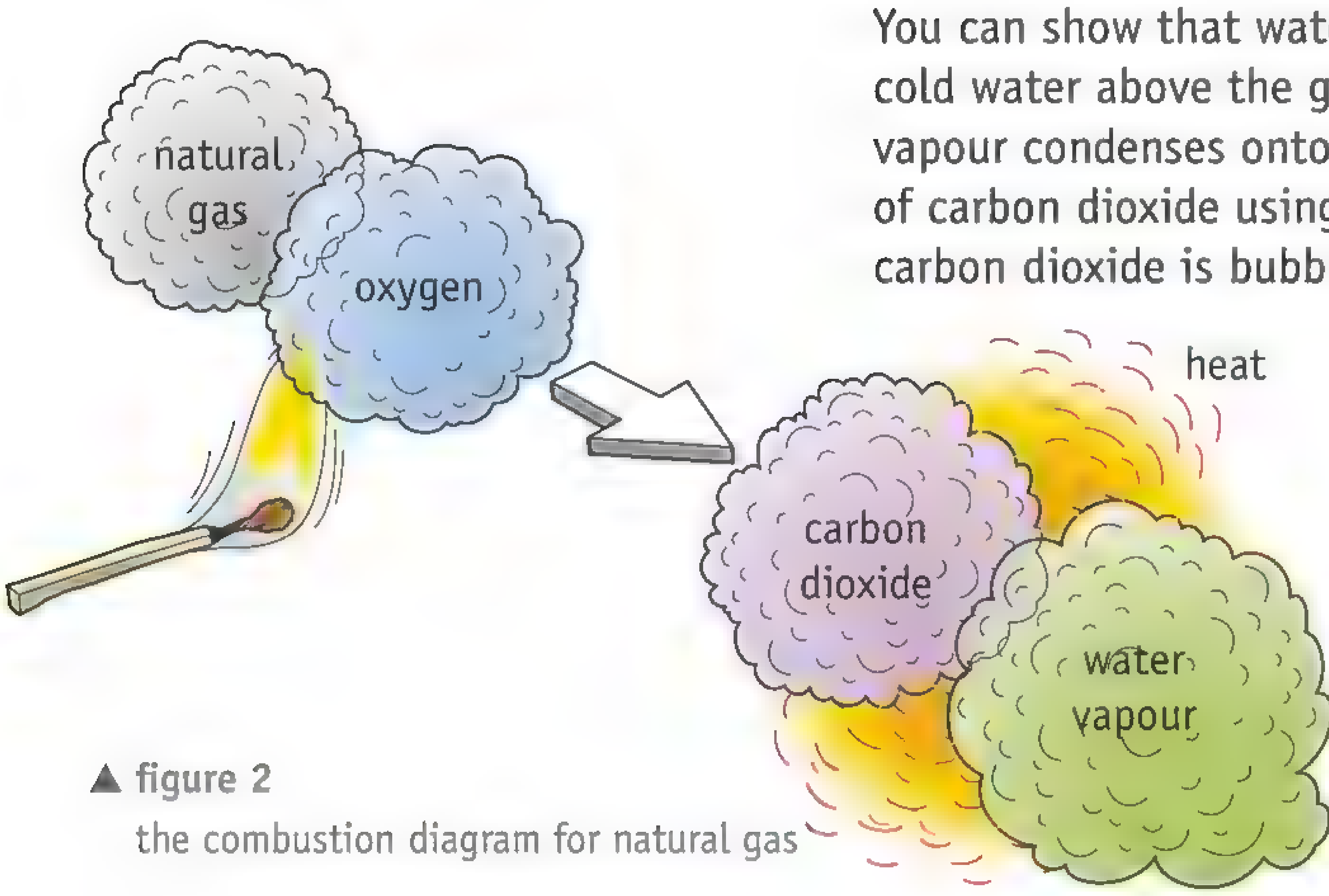
Oxygen and combustion

You need oxygen if you want to burn anything. The flame of a Bunsen burner, for instance, uses not only natural gas but also oxygen from the air. That is why there must always be a sufficient supply of fresh air if you are working with a burner. It makes sure that the flame gets enough oxygen and – much more importantly – that you can also continue to breathe properly.

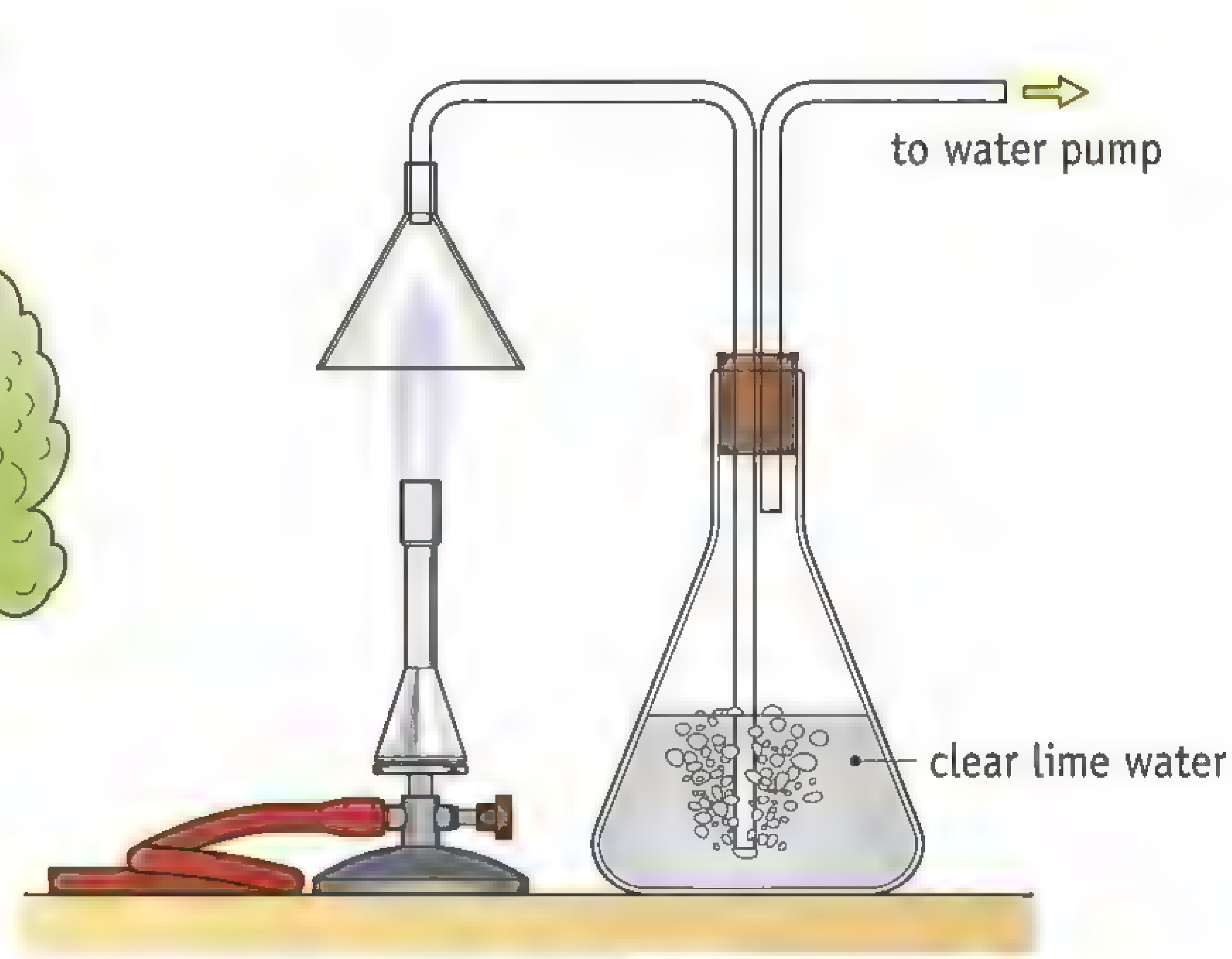
A mixture of natural gas and air will not start burning of its own accord; you have to get it started with a match or lighter. This makes sure that the necessary **ignition temperature** is reached. Every flammable substance has its own ignition temperature. For natural gas, it is about 630 °C.

When you burn natural gas, two substances are consumed: natural gas and oxygen. Instead of them, you then get hot **combustion gases:** water vapour and carbon dioxide (figure 2). You cannot see these gases, just as natural gas and oxygen are invisible. But you can do experiments to demonstrate that they are present.

You can show that water vapour is produced by holding a glass beaker of cold water above the gas flame. The glass will fog up because the water vapour condenses onto the cold glass. You can demonstrate the presence of carbon dioxide using limewater. Limewater is clear, but goes cloudy if carbon dioxide is bubbled through it (figure 3).



▲ figure 2
the combustion diagram for natural gas



▶ figure 3
Detecting carbon dioxide.

The atmosphere

There is a layer of air called the **atmosphere** around the Earth (figure 4). Beyond that there is only 'empty' space. An airless space is called a **vacuum.** You cannot really say how thick the atmosphere layer is, because the air gets thinner and thinner as the altitude increases. When you get high enough, the atmosphere changes imperceptibly into the vacuum of the universe.

▶ figure 4
This photo shows really well how thick the atmosphere is.

▲ figure 5
Living in the Andes, five kilometres above sea level.

Because the air is getting thinner, that means that the same volume will contain fewer and fewer molecules. At an altitude of 5500 metres, the number of molecules per m^3 is about half what it is at sea level. At the top of Mount Everest, 8850 metres above sea level, there are in fact only about one third as many molecules.

Above a certain height, the air is so thin that people start to suffer from the lack of oxygen. You do not actually have to go very many kilometres upwards for that. By the time you get more than six kilometres above sea level, there are no more people living there. On the highest mountains (eight or nine kilometres above sea level), the air is so thin that most mountaineers need oxygen cylinders.

So the layer of air in which people can live without special equipment is only six kilometres thick. That is very little indeed, compared with the dimensions of the Earth. If the Earth was the size of a football, this layer of air would be less than one millimetre thick.

Plus Altitude sickness

When you go rapidly from sea level to high altitudes (more than 3 km above sea level), your body responds immediately. You will spontaneously start breathing more quickly and your heart will beat faster. This is how your body attempts to keep its oxygen intake high enough. Despite those changes, your blood contains less oxygen at high altitudes than it does at sea level.

The shortage of oxygen makes some people ill. They feel miserable, they become fatigued quickly and they sleep poorly. This altitude sickness often disappears spontaneously after a few days. There is also a severe form of altitude sickness in which fluid accumulates in the lungs or brain. This form of altitude sickness is life-threatening.

People with severe altitude sickness must come down to lower altitudes as soon as possible. If the condition has not progressed too far, the symptoms then disappear again. If bringing them down quickly is not feasible, the victim can be put in a Gamow bag: an inflatable, airtight bag that air can be pumped into from the outside. The victim can then recover sufficiently to let them descend, either by themselves or with the help of others.

◀ figure 6
Climbing slowly helps keep altitude sickness under control.

Exercises

1 Answer the questions below.
- **a** What two gases together make up almost all the air?
- **b** Which other gases occur in air? Name two.
- **c** Why is carbon dioxide indispensable for life on Earth?
- **d** What do you call a volume in which there is absolutely nothing, not even air?

2 Copy and complete:
A combustion reaction only occurs if three preconditions are met.
1. You need a ......, such as natural gas or petrol.
2. There must be a sufficient supply of ...... (in the air).
3. You must make sure that the ...... is reached.

3 When natural gas is burned, how can you demonstrate that:
- **a** water vapour is produced?
- **b** carbon dioxide is produced?

4 Anna wants to light a burner. She opens the gas control knob.
Make a drawing of a Bunsen burner and state:
- **a** how you can ignite the mixture of natural gas and air.
- **b** how you can adjust the supply of fuel to the gas flame.
- **c** how you can adjust the supply of oxygen to the gas flame.

5 If the fat in a frying pan gets too hot, it can suddenly catch fire (figure 7). A particularly unflappable cook can then extinguish the fire by putting a lid on the pan and turning the gas off.
Explain:
- **a** why the fire goes out if you can slip a lid carefully on top of the chip pan.
- **b** why the fat begins to burn again if you lift the lid off again straight away.
- **c** why you should never try to put out a chip pan fire with water.

▼ **figure 7**
fire in the kitchen

Hot frying pan causes fire

SOEST – A fire in a flat in Soest has damaged its kitchen badly. The resident of the flat on Smitsweg had forgotten the frying pan, and it caught fire a little later.
The police were the first on the scene and they were able to extinguish the fire. They had to force a window and a door first to get access. The resident of the flat got away with no more than a fright, but was examined by paramedics for smoke inhalation.

▲ figure 8
vacuum-packed cheese

6 Food products such as cheese and salami are often vacuum-packed (figure 8).
- **a** What are the advantages of vacuum-packing food products?
- **b** How can you feel whether a piece of cheese or salami has been vacuum-packed?
- **c** What do you hear when you open a vacuum-packed bag of ground coffee?
- **d** What causes the noise that you hear then?

7 Mountaineers sometimes take cylinders of oxygen up with them.
- **a** Why do most climbers need extra oxygen to climb the highest peaks in the Himalayas?
- **b** Why do mountaineers not need to take oxygen cylinders with them when they go climbing in the Alps?

8 Search the Internet for information about flying in the stratosphere.
- **a** Why do large airliners fly for most of the journey high in the stratosphere, at an altitude of about 10 km?
- **b** What is a pressurised cabin? Why is a cabin like this indispensable for a modern airliner?
- **b** The windows in an airplane are made to be exceptionally strong. The Plexiglas in them is virtually unbreakbable.
  What would the consequences be for the passengers if the Plexiglas in one of those windows was to break during the flight? Explain your answer.

*9 A school in Amsterdam has classrooms that are 7.5 m long, 6.8 m wide and 3.0 m high. The air in the classrooms has a density of 1.2 kg/m^3.
- **a** See 'Skills 12' at the back of the book.
  Calculate the mass of air in a single classroom.
- **b** A school in Switzerland has classrooms of exactly the same dimensions as the one in Amsterdam.
  Do the classrooms here contain the same mass of air as you calculated for point a? If not, why not? Explain your answer.

Plus Altitude sickness

10 Mountaineers can suffer from altitude sickness when they climb high mountains.
- **a** What causes this altitude sickness?
- **b** What is the best thing for a mountaineer with severe altitude sickness to do?
- **c** Mountaineers are less likely to suffer from altitude sickness if they climb slowly.
  Explain why.

***11** If a mountaineer is suffering from severe altitude sickness, you can put them in a *Gamow bag*.
Read the text in figure 9 and answer the questions.
- **a** Why does the victim recover after staying in the bag?
- **b** Why is it important that the bag has an airtight zip?
- **c** Why does fresh air have to keep being pumped inside?
- **d** Why are air vents also needed to allow the air to keep escaping?

The *Gamow* bag

To keep a climber with severe altitude sickness alive, what is known as a Gamow bag is used. When set up ready for use, the Gamow bag is a kind of pumped-up airbed that the climber is shut inside.
The bag is usually kept pressurised from outside with a foot pump. The pumping frequency is eight to ten times a minute. The bag has two pressure valves that open automatically if the pressure inside becomes too great.
The Gamow bag simulates the prevailing conditions kilometres lower down, ensuring that the climber in the bag gets more oxygen with each breath. Research has shown that this is an effective way of combating the symptoms of altitude sickness.

▲ figure 9
How a Gamow bag works.

2 Air pressure

Your life is lived at the bottom of a sea of air. That air exerts a pressure on you, just like water does if you dive to the bottom of a swimming pool. You often do not feel the air pressure at all. But if you ascend or descend quickly, for example in a lift, you notice the 'pressure in your ears' telling you that the air pressure is there.

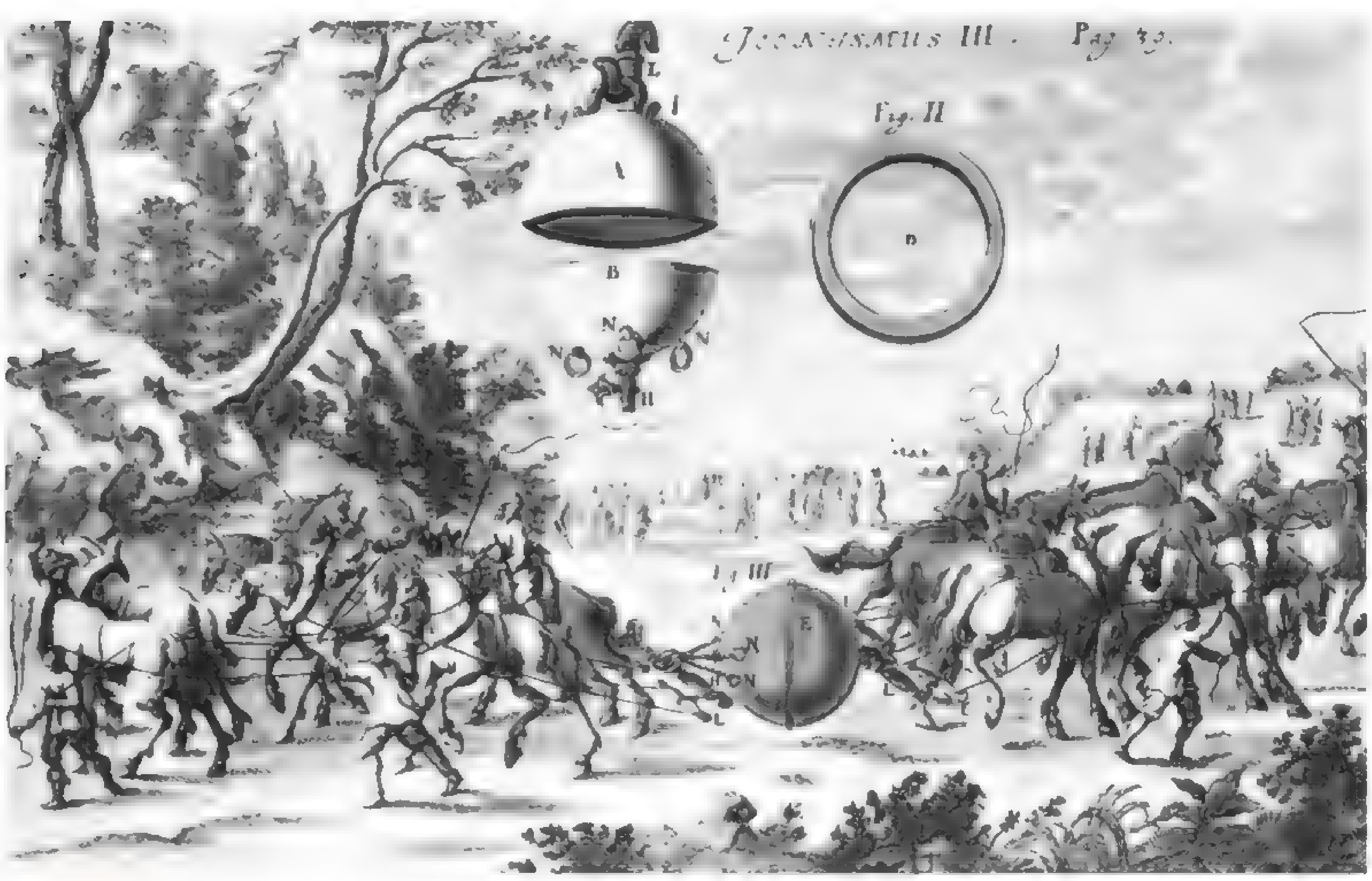
Atmospheric pressure

Experiment 2

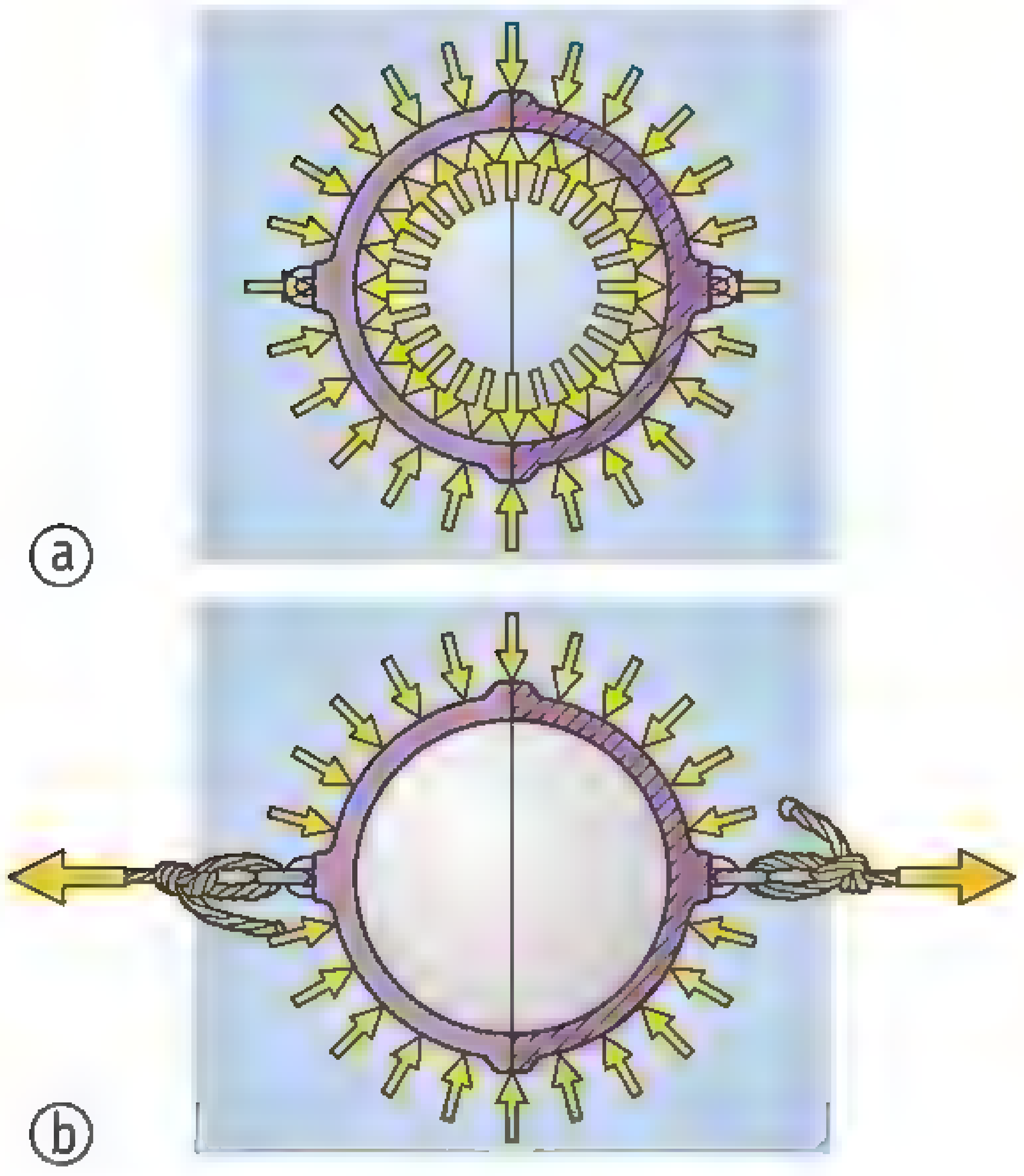
Although the density of air is low, all that air above your head nevertheless represents quite a substantial weight. This means that the air exerts a pressure on everything that is on the Earth. This pressure is known as the **air pressure** or **atmospheric pressure.**

You do not generally notice the air pressure at all. That is why all sorts of experiments have been thought up that show you how much air pressure there is. A famous example is the experiment known as the 'Magdeburg hemispheres'. In this experiment, two hollow half spheres are placed up against each other and the air inside them is then pumped out. It is then impossible to pull the two hemispheres apart.

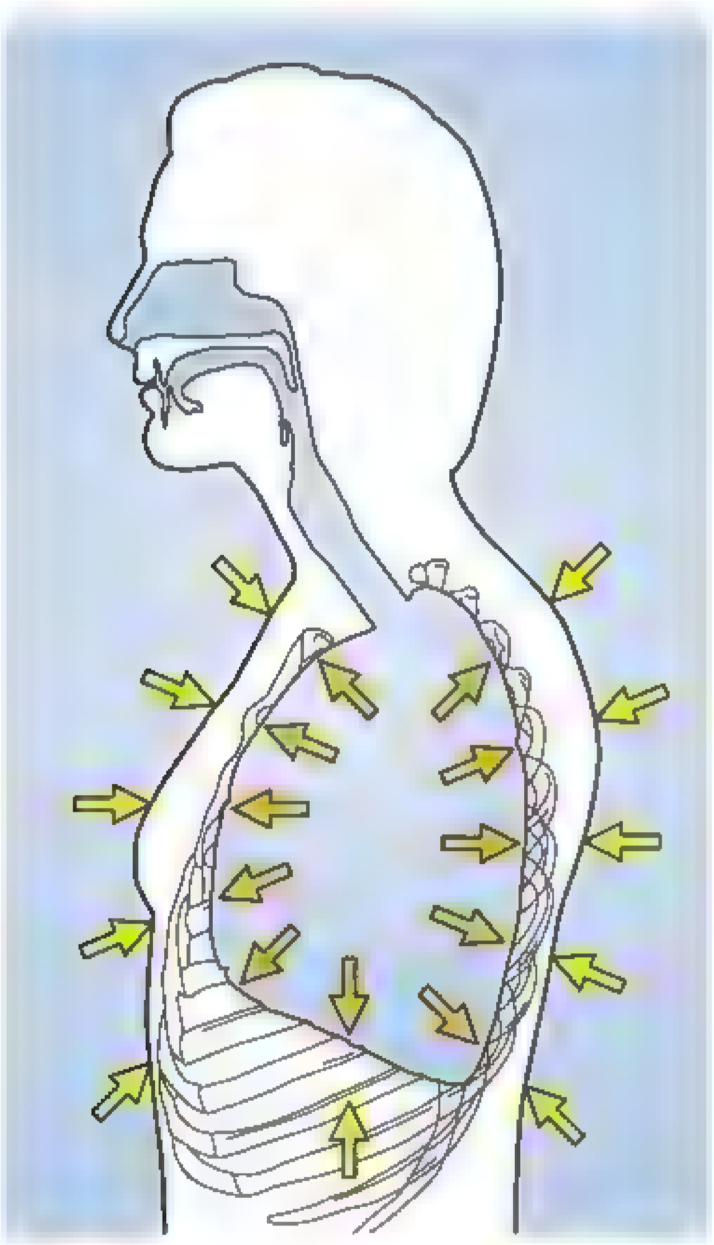
The 'Magdeburg hemispheres' experiment was first done in 1654 in the German town of Magdeburg. Otto von Guericke, a scientist with a good sense of publicity, turned it into a grand spectacle (figure 10). He brought on sixteen horses to pull against the air pressure, but even they could not separate the two hemispheres.



▶ figure 10
The two half spheres could not even be pulled apart by sixteen horses.



▲ figure 11
The counter-pressure disappears when the air enclosed by the two hemispheres is pumped out.



▲ figure 12
The counter-pressure in your lungs prevents your ribcage from collapsing inwards.

Air pressure and counter-pressure

Experiment 3

When you place the two hollow hemispheres together, they do not stick together spontaneously. As long as there is still air inside them, you can easily pull the two halves apart. The air that is inside the hemispheres exerts a counter-pressure that is just as strong as the air pressure outside (figure 11a). The air pressure and the counter-pressure then balance each other out.

That changes if you pump out the air from between the two hemispheres. There is no longer any counter-pressure then. All that remains is the air pressure from the outside. And that presses the half spheres very firmly together (figure 11b). Note that this pressure comes from all directions at once, not just from above!

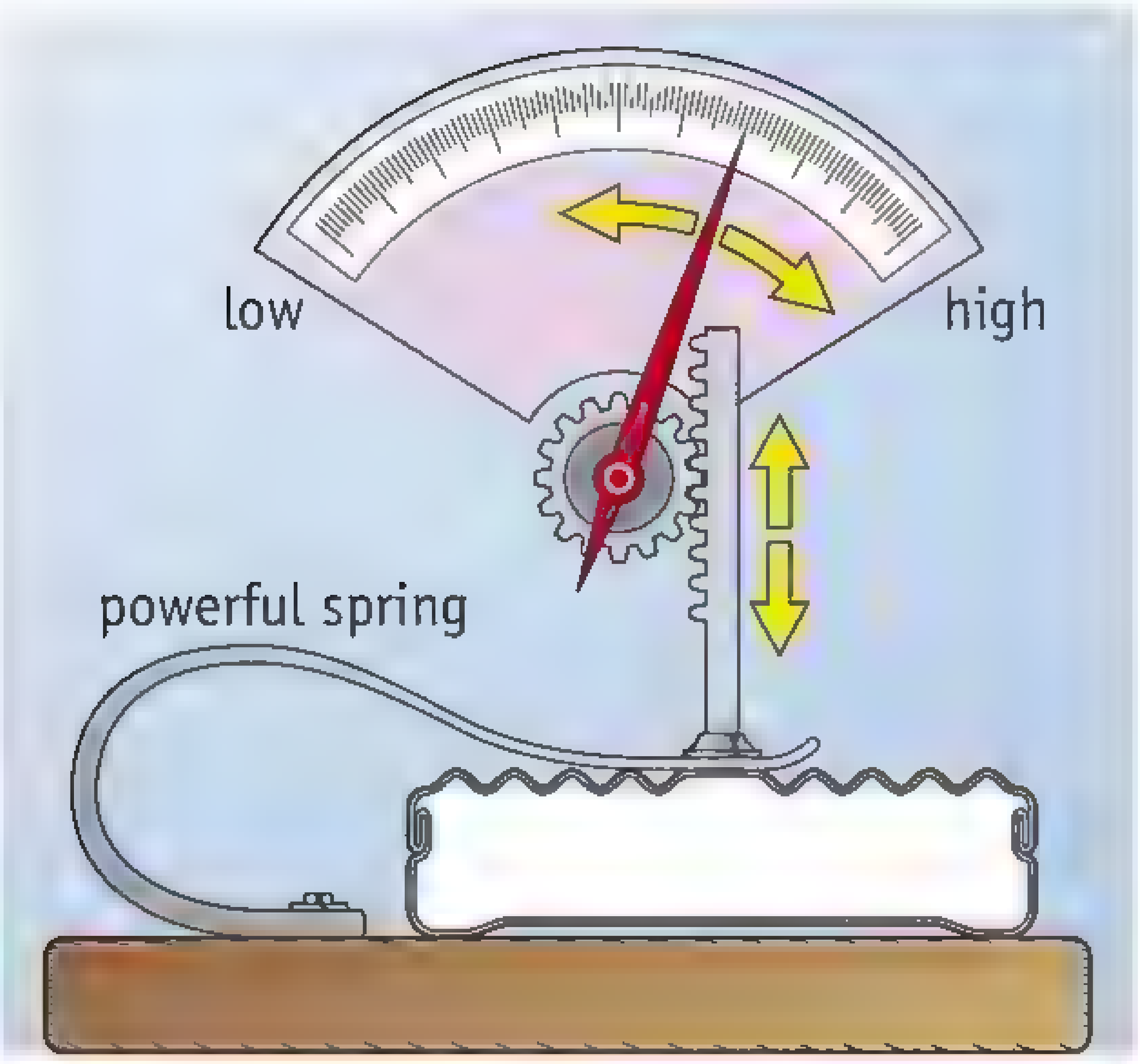
You only notice the effects of air pressure when the air pressure and the counter-pressure are not equal. That applies to you too. Your body contains various hollow (or nearly hollow) spaces, such as your lungs. Nevertheless, your ribcage is not crushed by the air pressure outside. This is because your lungs are filled with air. That air exerts a counter-pressure that is just as strong as the air pressure outside (figure 12).

Barometers

You can use a **barometer** to measure the air pressure. Figure 13 shows a device known as an aneroid barometer. It contains a metal box from which most of the air has been pumped out. A powerful spring makes sure that the air pressure is unable to squash the box entirely flat. The upper and lower sides of the box are corrugated (ribbed) and very thin; this allows them to move up and down easily.

▶ figure 13
a barometer

When the air pressure increases, the box will be compressed a little more: the top of the box will move downwards a bit. When the air pressure decreases, the opposite happens: the top of the box moves upwards a fraction. These movements of the top of the box are transmitted to a pointer. The pointer indicates the air pressure on a dial face (figure 14).



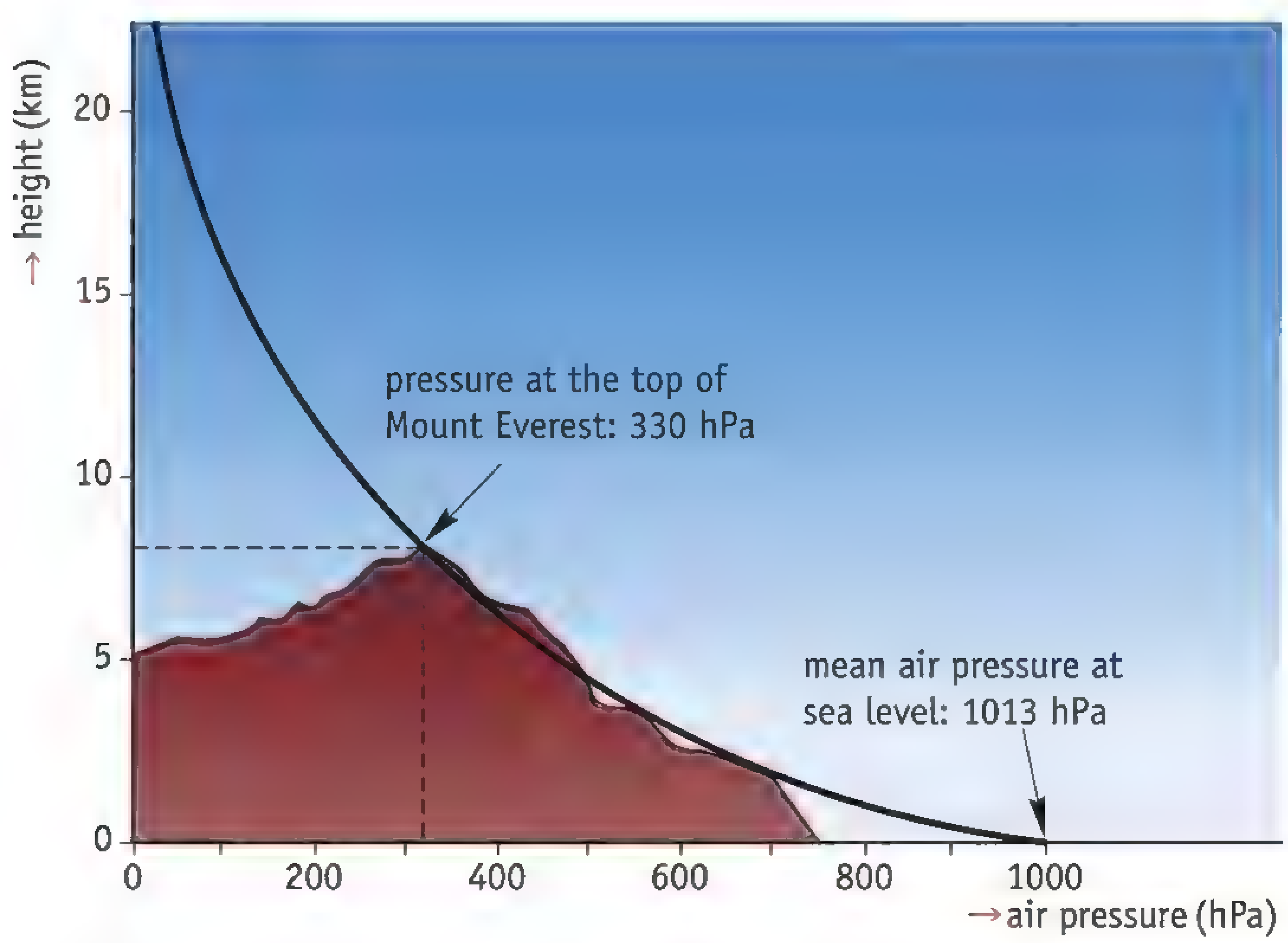
▲ figure 14
how a barometer works (diagram)

How high is the air pressure?

The unit of pressure is the pascal (Pa). Weather reports give the air pressure in hectopascals (hPa). 1 hPa = 100 Pa. The air pressure is often given by barometers and on weather charts using the old unit, the millibar (mbar). It makes no real difference, because 1 mbar is exactly the same as 1 hPa.

If you look at a barometer regularly, you will notice that the air pressure is not constant. The pressure can be quite a bit higher or lower on one day than on the next. That does not mean that the air pressure can take on just any value, though. The air pressure at sea level is almost never lower than 950 hPa or higher than 1050 hPa. The average air pressure at sea level is 1013 hPa. This value is therefore roughly in the middle of the scale.

Air pressure decreases with height: the higher you go, the lower the air pressure is (figure 15). This is because the amount of air still above your head becomes less and less as you ascend. At an altitude of 5.5 km above sea level, half the molecules in the atmosphere are already below you. The air pressure at that height is therefore only half the pressure at sea level.



▶ figure 15
the relationship between altitude and air pressure

Plus Air pressure and boiling point

High in the mountains, the air pressure is quite a bit lower than at sea level. You will notice that because you breathe more rapidly in the mountains and you get short of breath more quickly. The air pressure also affects the boiling point: as the air pressure decreases, the boiling point also drops. This is because it is easier for bubbles of vapour to form if there is less air pressure trying to compress the vapour bubbles.

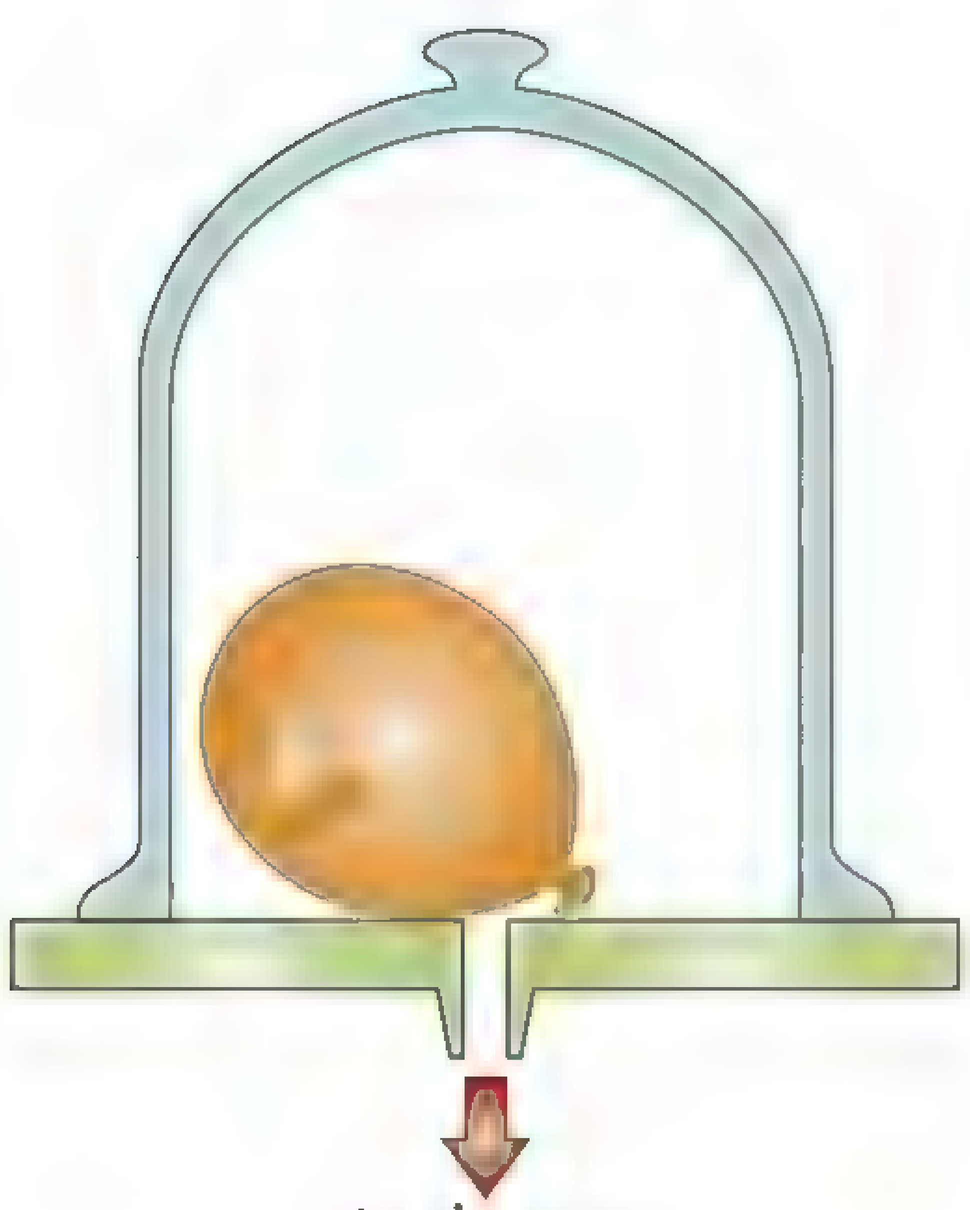
Boiling points in tables are generally listed at 1013 hPa, the average air pressure at sea level. The boiling point of water at that air pressure is 100 °C. As you ascend, the boiling point gradually falls. At an altitude of 5.5 km, water boils at 80 °C. That is very noticeable if you are cooking at altitude: it takes much longer before the food is cooked through.

Exercises

12 Answer the questions below.
- **a** What causes the pressure that the atmosphere exerts on you?
- **b** What measuring instrument can you use for measuring air pressure?
- **c** In what units is the air pressure expressed in a weather report?
- **d** What is the average atmospheric pressure at sea level?
- **e** At what altitude is the air pressure 50% of the pressure at sea level?

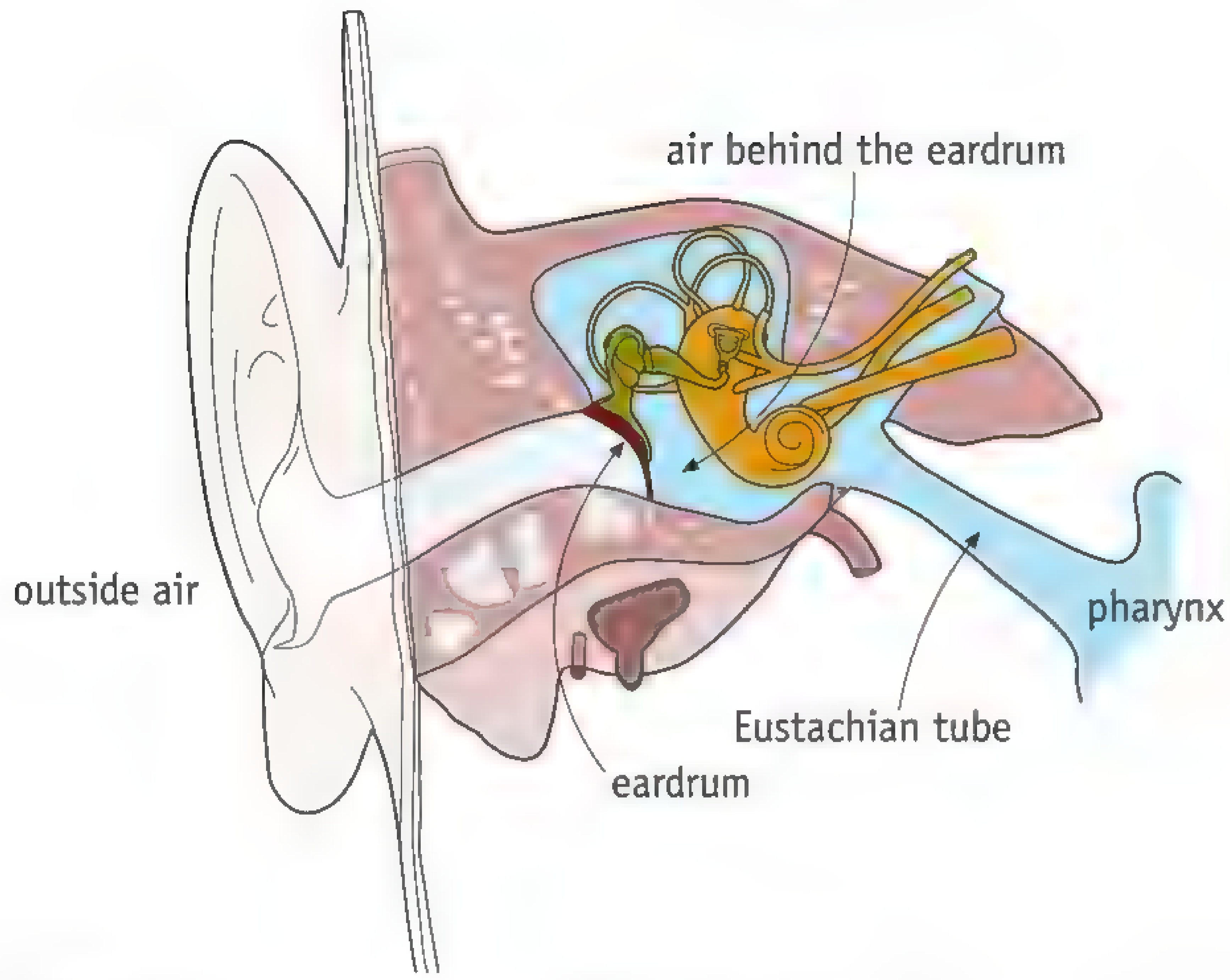
13 All the air above you adds up to quite a substantial weight. The force it exerts on your ribcage is roughly the same as the weight of a family car. So why isn't your ribcage crushed inwards?

14 Jake puts a half-inflated balloon under a glass bell jar. He then connects up an air pump that sucks the air away from under the bell jar (figure 16).
- **a** What does the balloon look like when (almost) all the air has been pumped out from under the bell jar?
- **b** Give an explanation for this. Use the terms 'air pressure' and 'counter-pressure'.
- **c** You can substitute a dab of shaving cream or a soft marshmallow for the balloon.
  Explain why you then see something similar happen.



▲ figure 16
an experiment with a half-inflated balloon

15 If you drive up a steep hill quickly in a car the change in atmospheric pressure can affect your ears. A pressure difference has been created between the outside air and the air behind your eardrum (figure 17).
- a On which side of the eardrum is the pressure greater?
- b When you go back down the hill, your ears may start hurting again. On which side of the eardrum is the pressure greater now?
- c You notice pressure differences most strongly if the Eustachian tubes are blocked. Explain why.



▲ figure 17
cross-section of an ear

16 Study figure 14 and imagine that the air pressure slowly increases.
- a What happens to the corrugated top surface of the box?
- b In which direction will the pointer of the barometer then move?

17 The graduated scale on a barometer goes from 950 to 1050 mbar. Explain:
- a why the designers decided to start at 950 and end at 1050 mbar.
- b why a barometer like that is fine for measuring the air pressure anywhere in the Netherlands.
- c why a barometer like that cannot be used everywhere in countries such as Austria or Switzerland.

18 Ewan is going to climb a mountain. He bought a bag of potato crisps for the trip and put it in his rucksack. At the top of the mountain, he sees that the bag is now distended, as if blown up. Give an explanation for this.

19 Search the Internet for information about aircraft altimeters.
- a How does a pressure altimeter, like the ones used in many planes, work?
- b What units are used internationally for expressing the aircraft's flying altitude?
- c What level is the flying altitude referenced against?
- d Why does air traffic control pass on the local air pressure before take-off?

▼ **table 1** a balloon trip

time (min)	pressure (mbar)	height (m)
0	1015	
1	988	
2	976	
3	970	
4	965	
5	962	
6	961	

***20** You need worksheet 4-1 for this exercise.
Reena has won a balloon trip in a competition. Before they leave, the pilot tells her why they have a barometer on board. "You can use a barometer to tell how high up you are. As a rule of thumb, you can assume that a pressure difference of 10 mbar corresponds to a height difference of 80 m. That's not exact, but for the heights we'll be at, it's accurate enough."
Table 1 shows you how the pressure dropped during the first five minutes of the balloon trip.

- **a** Copy the table.
  Calculate the missing heights and note them down in the table.
- **b** Complete the height-time diagram on the worksheet.
- **c** Suppose that the air pressure at ground level dropped after the balloon took off.
  What would that mean for the heights that you have calculated for point a: would the actual altitude then be higher or lower? Explain.

Plus Air pressure and boiling point

21 Tom is doing an experiment with an air pump. He fills a glass beaker half full with water (at room temperature) and puts it under a glass bell jar. Then he pumps the air out from beneath the bell jar. The water in the beaker then soon starts to boil.
Why can water boil even at room temperature if you pump away the surrounding air? Explain.

***22** La Paz in Bolivia is the highest capital city in the world, at an elevation of 3800 m above sea level. You have to learn to adapt to living at this altitude. A special cookery book has even been written for cooking at high altitudes.

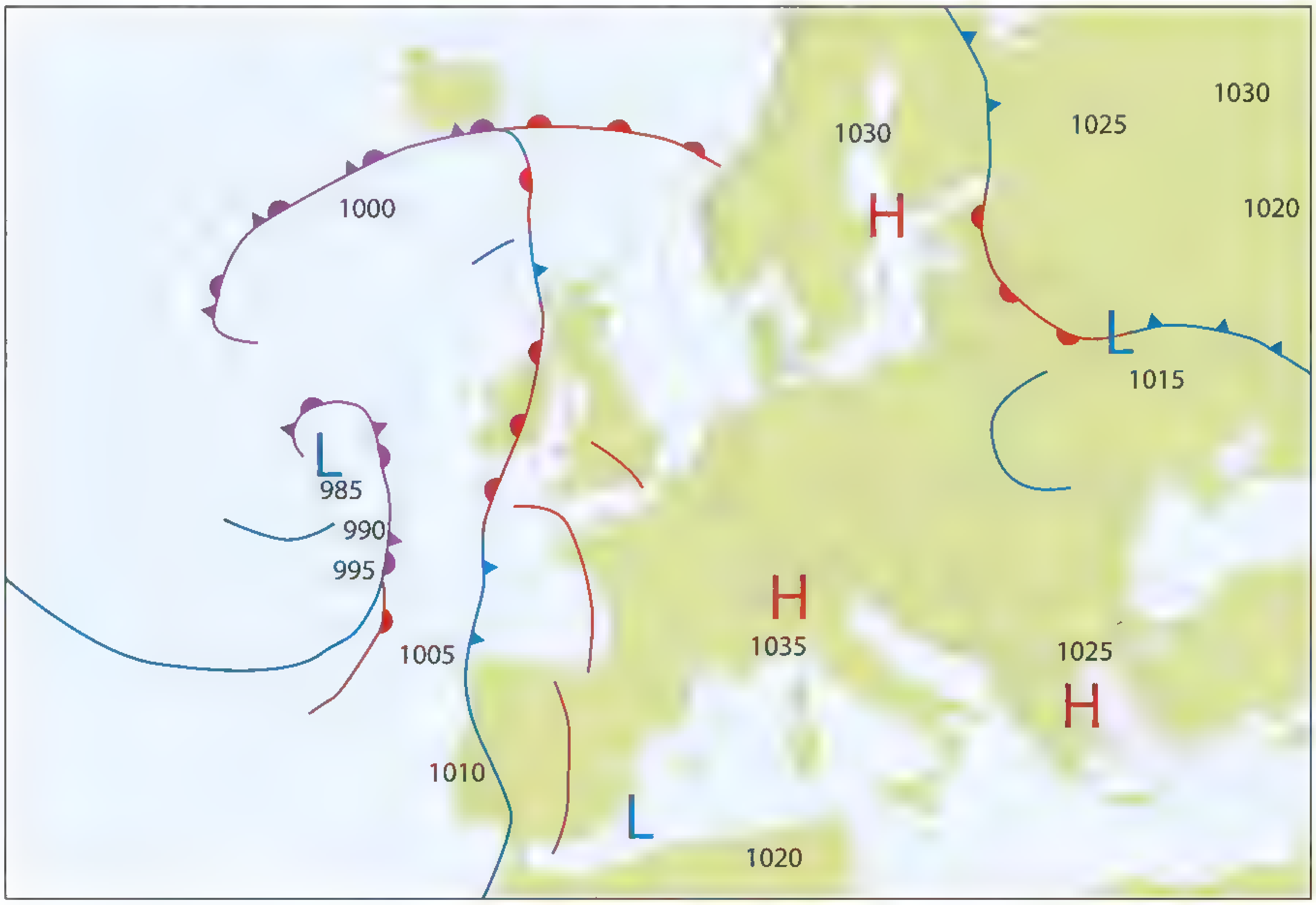
- **a** What will the cookery book undoubtedly warn you about when it discusses cooking potatoes?
- **b** The cookery book says, "Allow for the fact that bread dough will rise much more quickly at high altitudes than it does at sea level."
  Explain what causes this difference in the rising time (think up your own reasons).
- **c** A travel guide contains the following tip: "If you enjoy eating on time, it is well worth buying a pressure cooker." A pressure cooker is a closed pan in which the pressure is higher than the atmospheric pressure outside the pan.
  Explain why buying this type of pan might help you get to eat on time.

3 Wind

The air pressure varies from one place to another. When the air pressure in Amsterdam is 1015 mbar it is perfectly possible for the air pressure in London to be 1020 mbar and for it to be 1010 mbar in Berlin. The differences in air pressure make the air move and winds are created.

High pressure and low pressure

Meteorologists gather measurements from a large number of weather stations. This means that they know how high the air pressure is all over the world. They summarise all this information by drawing **isobars** on a weather chart. Isobars are lines that connect places where the air is at the same pressure. The pressure difference between any two successive isobars on the weather chart in figure 18 is 5 hPa.



▶ figure 18
a weather map

Some areas on the weather chart are entirely enclosed by one or more isobars. If the air pressure in such an area is higher than the pressure outside, it is called a **high pressure area** or a 'high'. If the air pressure in such an area is lower than the pressure outside, it is a **low pressure area** or a 'low'. High pressure areas are designated on a weather map with a capital H and lows are marked with a capital L.

The weather in a high pressure area is generally calm and sunny. In the spring and autumn, there is also a risk of fog. A low often brings changeable weather, with a lot of wind and precipitation. You can therefore use

a barometer as a tool to help predict the weather. If the air pressure is rising, that is a sign that the weather will improve. When the air pressure is falling, it is very likely that the weather is going to get worse.

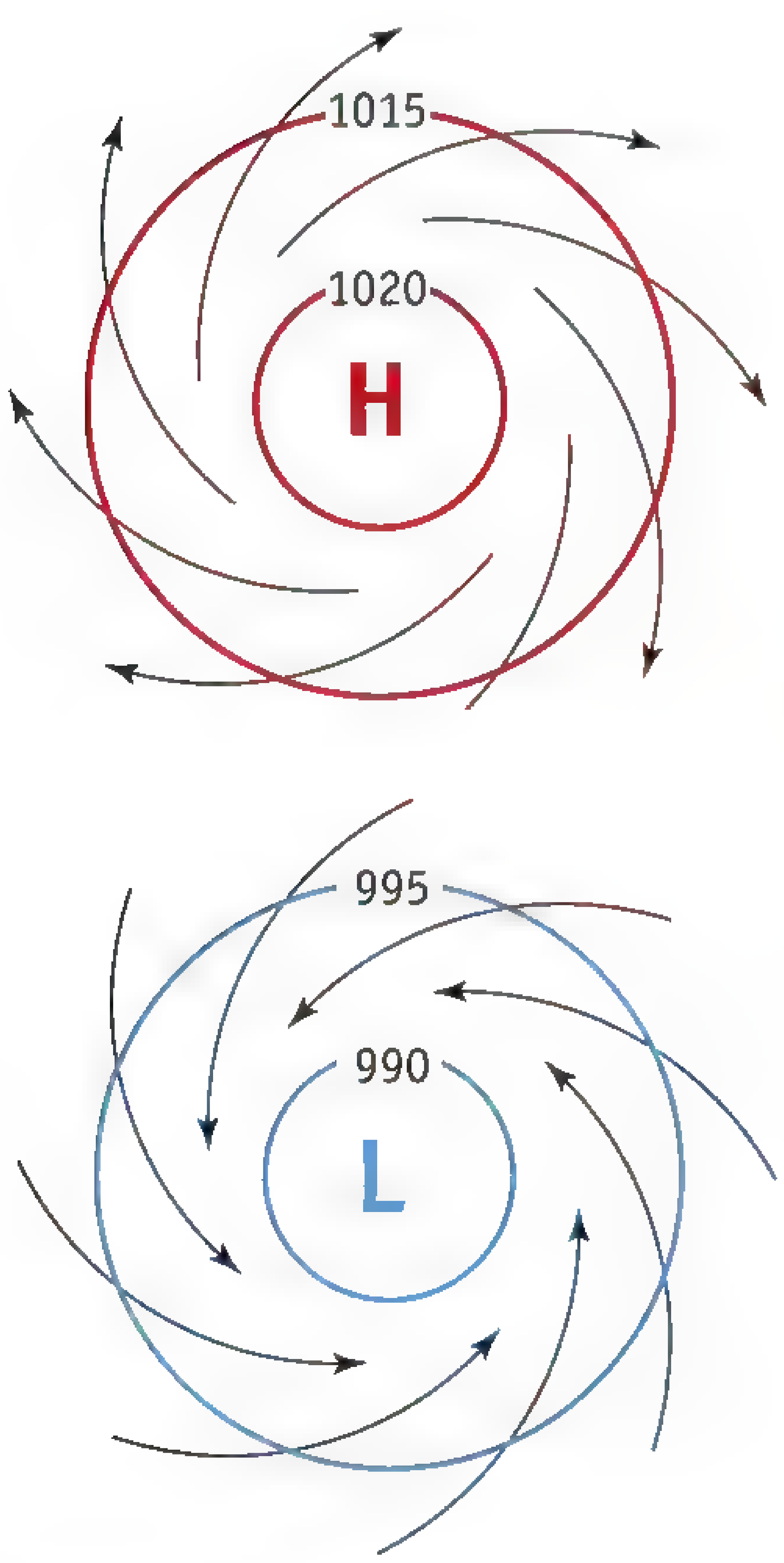
▲ figure 19
a weather vane (left) and an anemometer (right)

Wind direction and wind speed

The **wind direction** and **wind speed** are important data for meteorologists. The wind direction is the direction that the wind is coming from. You can use a weather vane to help determine the wind direction. The wind speed is the speed that the air is moving at and you can measure this with an anemometer (figure 19). Weather reports will often state the strength of the wind on the Beaufort scale. Table 2 shows you the relationship between the wind speed in km/h and the wind force according to the Beaufort scale.

Wind occurs because of pressure differences in the atmosphere. If the Earth was stationary the air would flow directly from the place with the highest air pressure to the place with the lowest air pressure. Pressure differences would then not last very long. In reality, though, the Earth rotates around its own axis once every twenty-four hours. The result of this is that the winds are deflected and will start to rotate around a high-pressure or low-pressure area.

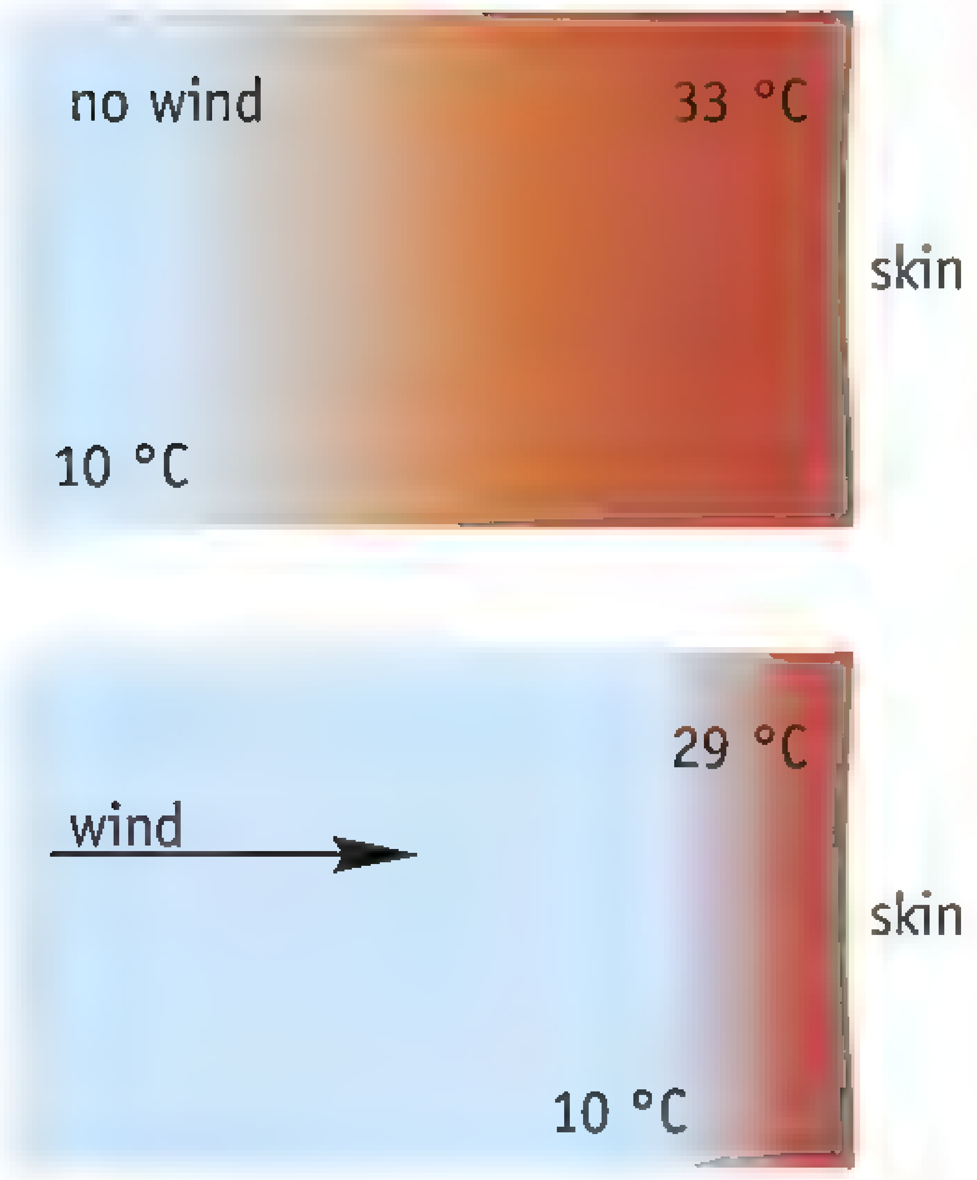
Figure 20 shows you how the winds move in the northern hemisphere. The winds around a low rotate anticlockwise. The wind moves in a spiral towards the centre of the low pressure area. The closer together the isobars are, the greater the wind speeds will be. The winds around a high rotate clockwise, away from the centre of the high pressure area.



▲ figure 20
the sense of rotation of winds in the northern hemisphere

▼ table 2 the Beaufort scale

wind force	average wind speed (km/h)	name
0	<1	calm
1	1-5	light air
2	5-11	light breeze
3	11-19	gentle breeze
4	19-28	moderate breeze
5	28-38	fresh breeze
6	38-49	strong breeze
7	49-61	near gale
8	61-74	gale
9	74-88	severe gale
10	88-102	storm
11	102-117	violent storm
12	>117	hurricane



▲ figure 21
the temperature of the air around the body: with no wind (above) and with wind (below)

Winds are cooling

On a sunny spring day with no wind, you hardly notice that the air around you is still cold. This is because the layer of air directly next to your skin warms up quickly. A layer of warm air has an **insulating** effect, it ensures that your body does not lose much heat to the cold air outside. This makes you perceive the temperatures as pleasant, particularly if the sun is shining too.

But if the wind then picks up on a spring day like that, you suddenly start to feel cold. It feels as if the air temperature drops suddenly. But if you look at a weather thermometer, you will see that it still indicates the same temperature. Apparently it is only the wind that is making your body feel colder. The air temperature has not changed.

The wind has this cooling effect because it blows away the insulating layer of warm air around your body. This lets the cold outside air get close to your body (figure 21). The result is that your body will lose more heat. Your skin cools down and you get cold.

If you are sweating, you will cool down even more. This is because the wind makes the perspiration on your skin evaporate more quickly. The evaporating sweat removes a lot of heat from your body. Sportsmen and women can therefore easily get too cold after a tough match. This is why you will often see them put on warm clothing immediately after the finish.

▲ figure 22
The insulating effect of the padded filling in a parka relies on the air enclosed within it.

Insulating with air

Air is a good **thermal insulator.** The padded filling in a parka keeps you warm because it consists largely of air. The air creates an insulating layer between your warm body and the colder air outside at e.g. 10 °C. Within the insulating layer, the temperature decreases steadily from about 30 °C close to your body down to 10 °C at the outer surface of the jacket.

Because the air is 'trapped' in the padding, it cannot easily be blown away by the wind. The outside of a parka is also made of a tightly woven material that blocks the wind effectively. This means that the insulating layer of air around your body is maintained, even if there is a strong wind.

When you put the parka on, you will not feel warm immediately. It takes a little while before the air in the padded filling has warmed up. You only really feel comfortably warm once your body heat has brought the air in the padding up to temperature.

Plus Subjective temperatures: wind chill

As well as the actual temperature, the weather forecast in the winter sometimes also gives the **wind chill** temperature. The meteorologists use this to make clear how cold you will subjectively feel it to be at that time. If it is very windy a temperature of –5 °C can feel just as cold as –18 °C in calm weather. This is because your body is losing heat equally quickly in both situations. The weather forecast then says: "The wind chill equivalent temperature today is minus 18."

The subjective temperature is only given in the weather forecast if it is particularly cold: an equivalent temperature of –15 °C or less. From about that temperature, there is a risk of unprotected parts of the body freezing. If wind chill makes temperatures feel as if they are below –20 °C, even warmly dressed people can easily be caught out by the cold. You then need extra windproof clothing to protect you properly (figure 23).

▶ figure 23
The wind chill factor meant that it felt colder than –15 °C at the Elfstedentocht skating race in 1997.

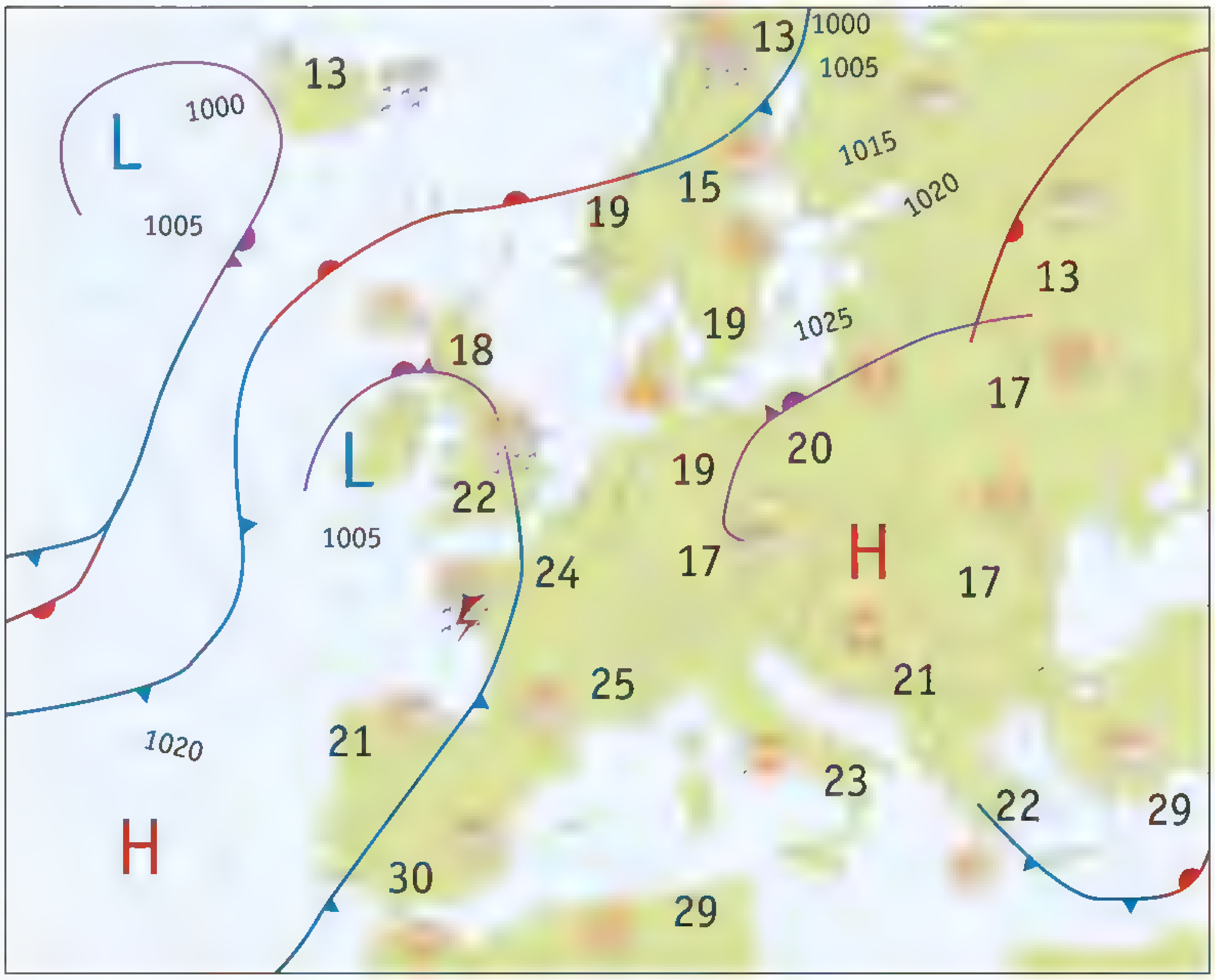
Exercises

23 Answer the questions below.
- a What is the name for the 'lines of equal pressure' that you see on a weather map?
- b What type of weather is usually associated with a high pressure area?
- c How does the air flow around a low pressure area in the northern hemisphere?
- d What measuring instrument does a meteorologist use to determine the wind direction?

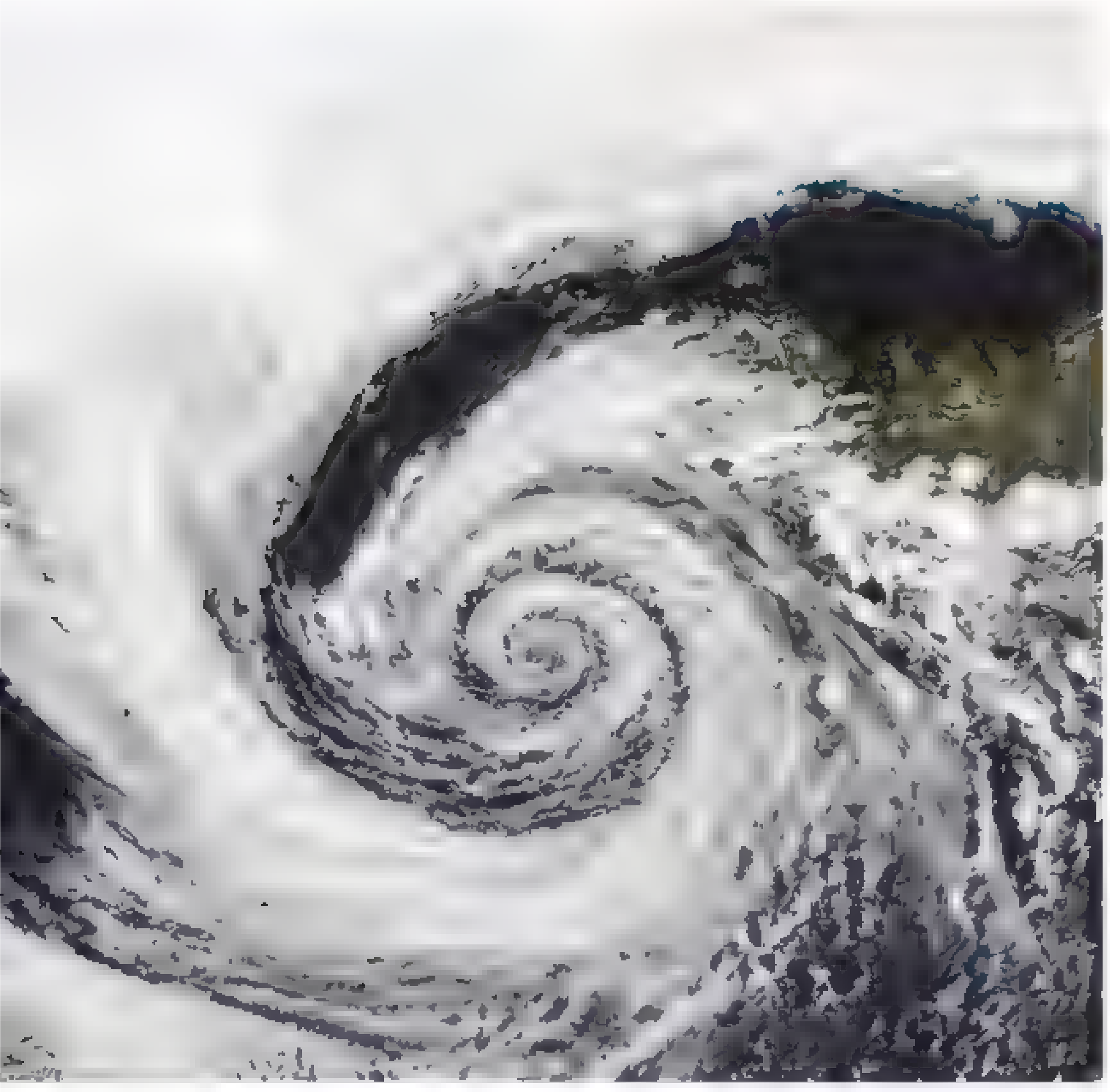
24 You are more likely to perceive the temperature as pleasant when there is no wind.
a Why does your body not lose much heat when there is no wind?
b If the wind suddenly picks up later in the day, you will feel colder. State two reasons why your body is then going to lose heat more quickly.

25 You can use a barometer as a tool to help predict the weather. What is the weather probably going to be like if, on a single day, the air pressure:
a rises from 1010 to 1025 hPa?
b falls from 1010 to 980 hPa?

26 Figure 24 shows a weather chart.
a Where in Europe is there a high pressure area at that time?
b What is the weather like in that area?
c Where in Europe is there a low pressure area at that time?
d What is the weather like in that area?
e What is the air pressure in the Netherlands?
f Is that a high, low or average value?



▶ figure 24
a weather map



▲ figure 25
a satellite photo of a low-pressure area

27 In figure 25 you can see a satellite photo of a low-pressure area.
- **a** How can you see that this is a photo of a low? Note two aspects.
- **b** Where is this low pressure area: in the northern or southern hemisphere? How can you tell?
- **c** Sketch how the wind is moving around the centre of the low. Mark the centre with a capital L.
- **d** The isobars around the low pressure area on a weather chart that was made on the same day are close together.
  What can you say about the wind on that day?

28 Sue cycles along a path at 22 km/h. She has the wind at her back, but at the speed she is cycling she cannot feel any wind at all.
- **a** What does it appear that the wind speed is at that moment?
- **b** What is the corresponding wind force?
- **c** Sue feels too hot. She gets off to take her jumper off, but then she suddenly finds that it is rather chilly.
  Give an explanation for this.

***29** Three statements about the wind are given below:
1. A moderate breeze is blowing.
2. It is a force 4 wind.
3. The average wind speed is 25 km/h.
- **a** Which statement gives the wind speed most precisely? Explain your answer.
- **b** Which statement gives the wind speed least precisely? Explain your answer.
- **c** Penny says, “Every step on the Beaufort scale corresponds to about 10 km/h more wind speed.”
  For which part of the scale does this statement apply reasonably well? And for which part does it not apply?

▲ figure 26
a starling in winter

30 Many animals can retain a layer of stationary air around their bodies (figure 26).
- **a** How does the starling make the layer of stationary air around its body as thick as possible?
- **b** How does this layer of stationary air benefit the starling?

***31** Houses are often insulated so that unnecessary heat loss is prevented. Insulation materials such as rock wool and polystyrene (also known as ‘Styrofoam’) are used for this. These materials consist largely of air. What is the advantage of having that air if you consider:
- **a** the purpose for which the material is used?
- **b** the density of the material?
- **c** the price of the material?

Plus Subjective temperatures: wind chill

32 As well as the 'real' temperature, the weather forecast in the winter sometimes also gives the wind chill temperature.
- **a** Explain exactly what is meant by a 'subjective temperature'.
- **b** Why does the weather forecast only mention a wind chill temperature from −15 °C or colder?

33 When the *Elfstedentocht* was held on 4 January 1997, the wind played a significant role, because it cooled the skaters down a great deal. Read the newspaper article in figure 27 about the relationship between the wind and this cooling effect.
- **a** Early on the morning of the 1997 *Elfstedentocht*, it was −12 °C with a force 5 wind on the Beaufort scale.
  What was the subjective temperature for spectators who were standing in the wind?
- **b** One of the people taking part, Nick, was skating past Stavoren with the wind at his back at a temperature of −7 °C. Nick was skating at the same speed as the wind, 13.4 m/s.
  What was the wind chill temperature for Nick then?
- **c** After passing Stavoren, Nick was skating into the wind. On top of that, he was skating into the wind created by his own speed. This meant that the air was flowing past Nick at a speed of 15.6 m/s. The air temperature was still −7 °C.
  Use the table to explain whether the wind chill equivalent temperature perceived by Nick meant that there was a risk of frostbite.

Wind chill

The temperature that you actually perceive is determined by the rate of heat loss from your skin. That loss of heat depends not only on the air temperature, but also on the wind speed. The harder the wind is blowing, the more rapidly you will lose heat and the colder you will feel. The 'wind chill' temperature can be read from the table. The table also indicates whether there is a significant risk of bare skin getting frozen.

Windchill factor

The wind chill temperatures at various wind speeds and the risk of bare skin freezing.

wind speed in...		air temperature in °C							
Beaufort	m/sec	+10	+5	−1	−7	−12	−18	−23	−29
0 calm	0.1	10	5	−1	−7	−12	−18	−23	−29
2 light breeze	2.5	9	3	−3	−9	−15	−21	−26	−32
3 gentle breeze	4.5	5	−2	−9	−16	−23	−30	−36	−43
4 moderate breeze	6.7	2	−6	−14	−21	−29	−36	−43	−50
4 fresh breeze	8.9	0	−8	−16	−24	−32	−40	−47	−55
5 strong breeze	11.2	−1	−9	−18	−26	−34	−42	−51	−59
6 high wind	13.4	−2	−11	−19	−28	−36	−44	−53	−61
6 high wind	15.6	−3	−12	−20	−29	−37	−45	−54	−63
7 fresh gale	17.9	−3	−12	−21	−30	−38	−46	−55	−64
risk of freezing		low				high			very high

▶ figure 27
How cold you feel depends on more than just the temperature.

4 Clouds and precipitation

Water is an important component of the atmosphere. It can be present not only as a gas but also as a liquid or a solid. Clouds appear when the water in the atmosphere changes phase, from invisible water vapour to visible water droplets or ice crystals (or a mixture of the two).

▲ figure 28
When the weather is warm, wet clothes dry out again quickly.

Water vapour in the air

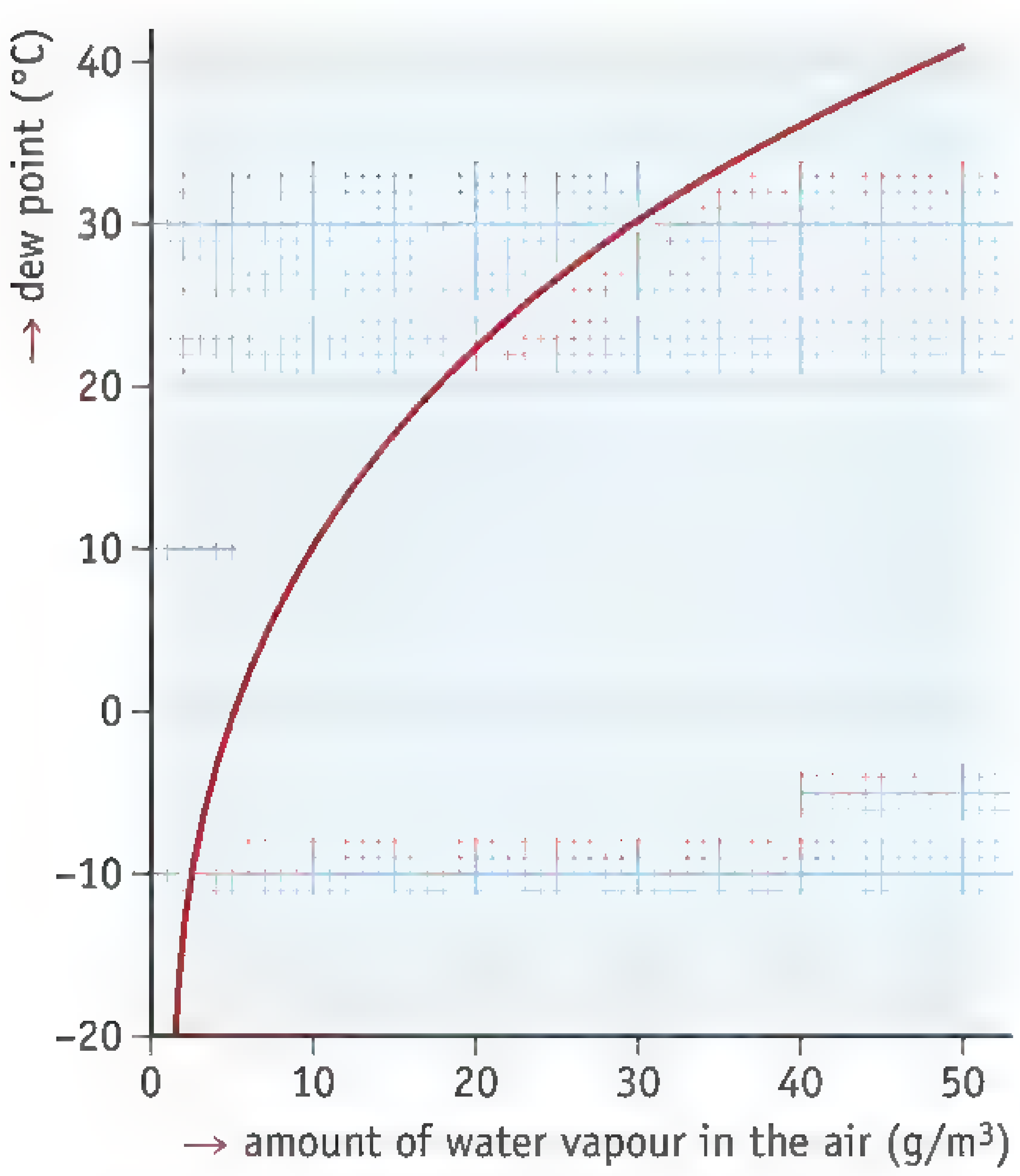
When water evaporates, the water vapour is absorbed into the air. This means that the air around you always contains water vapour, although the amount is very variable. The higher the temperature, the more water vapour the air can hold. That is why a tumble dryer blows hot air through the wet washing. Hot air takes up water much more easily than cold air would (figure 28).

If the weather during the day is warm, a lot of water evaporates and the air takes up large quantities of water vapour. The air then cools down again at night. The excess water vapour then condenses out as small water droplets. These droplets appear, in particular, at places where the air comes into contact with a cold surface. This is why dew occurs.

Dew points

The temperature at which the water vapour in the air condenses out is called the **dew point.** This temperature is not always the same. The more water vapour the air contains, the higher the dew point will be. Figure 29 shows you the relationship between these two variables. If the air contains:

- 5 g water vapour per m³, the dew point is 0 °C.
- 7 g water vapour per m³, the dew point is 5 °C.
- 10 g water vapour per m³, the dew point is 10 °C.
- and so forth.



▲ figure 29
the relationship between the amount of water vapour and the dew point

If the weather is clear and there are no clouds, it cools down quickly at night. It is then very likely that the temperature will fall to below the dew point. This is why grass is often soaking wet with dew after a clear autumn night.

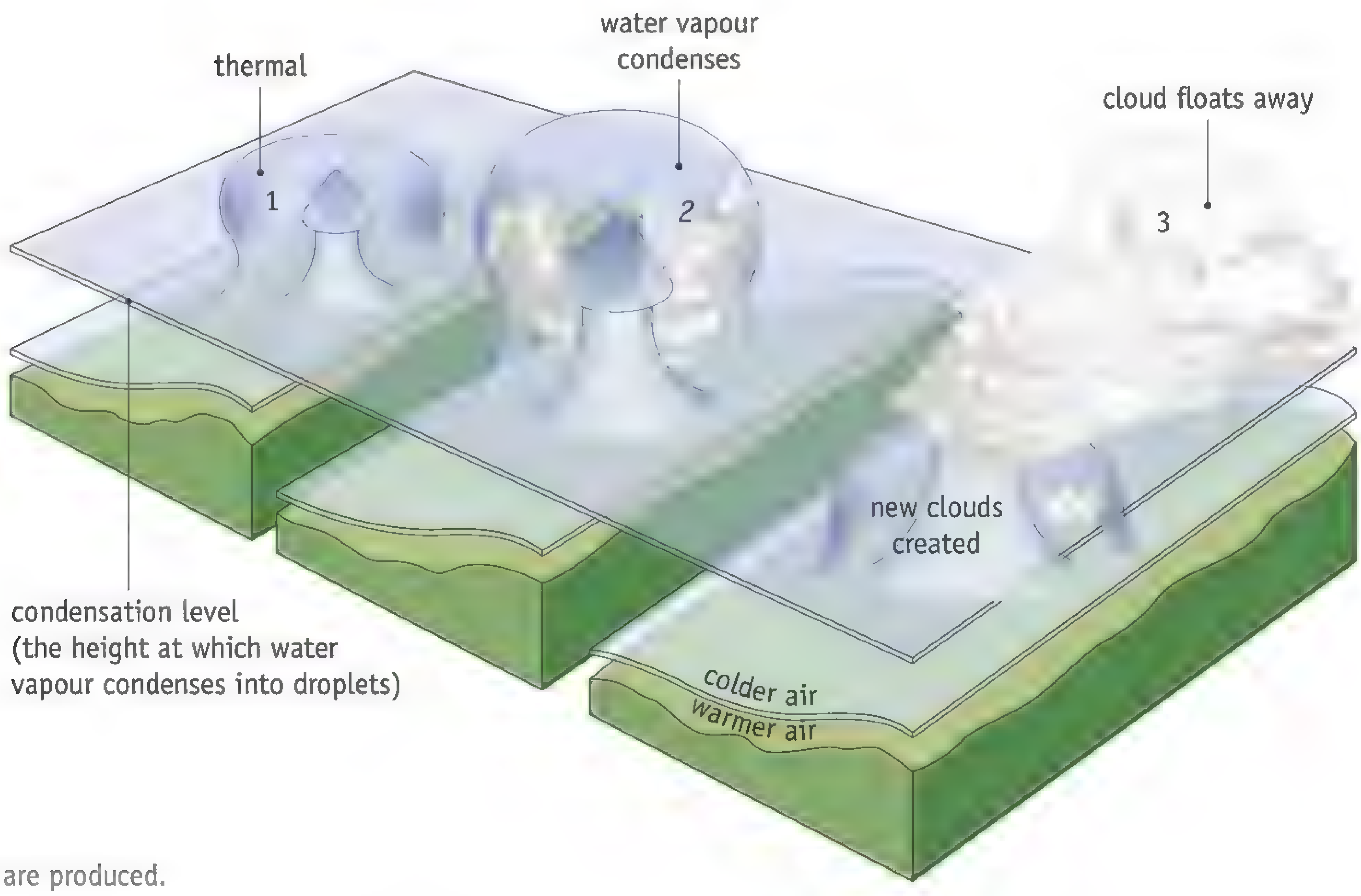
How cumulus clouds are created Experiments 4 and 5

When the sun heats the Earth's surface, the ground will become hotter at some places than at others. For example, a barren sandy plain will get hotter than a woodland area. If you walk around in bare feet, you can feel the differences very easily. At places where the ground heats up more, the air just above the ground will also become warmer. This generates big 'bubbles' of hot air.

As the air heats up, it also expands: the volume of the bubbles of hot air keeps increasing. The density of the warm air is therefore less than that of the surrounding, colder air. The result is that the bubbles of warm air move upwards, like invisible hot air balloons. We then say that a **convective flow** occurs in the air: an airflow that is created by a localised temperature difference.

As the bubble rises, the air inside it expands further and cools down. At a given moment, the temperature falls below the dew point. The water vapour in the bubble of air then starts to condense out. Very small water droplets are produced. The bubble of air then becomes visible, in the form of a cumulus cloud.

The bottom of a cumulus cloud is generally flat. This is the **condensation level,** the height at which the water vapour starts to condense out (figure 30). The top of a cumulus cloud shows how high the bubble of warm air has ascended.



▲ figure 30
How cumulus clouds are produced.

Fair weather clouds and rainclouds

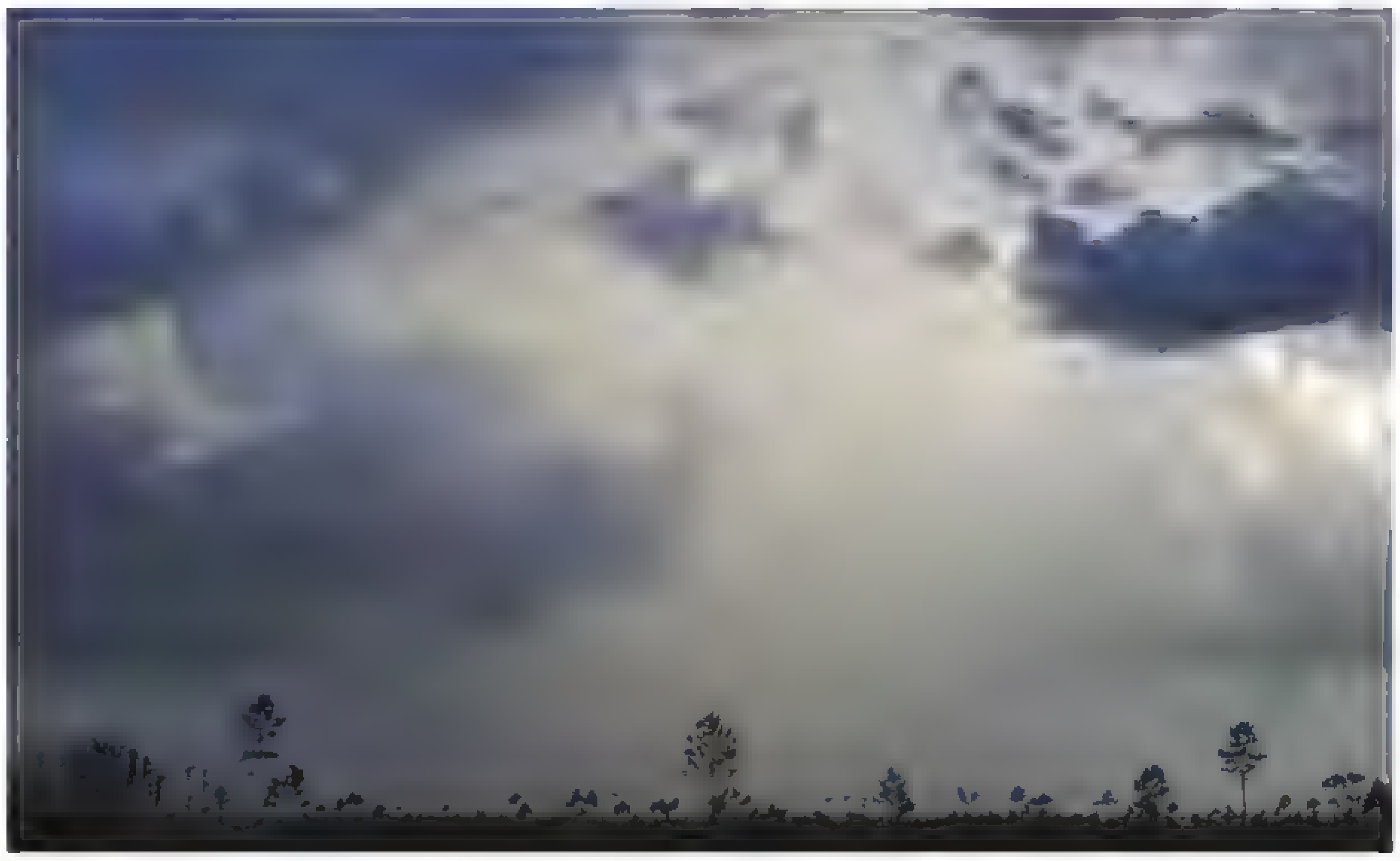
How high a bubble of warm air can rise depends on how the temperature changes as you go up through the atmosphere. If the air higher up in the atmosphere is relatively warm, a packet of hot air will only rise slowly and will not get to any great height. This then gives you a genuine 'fair weather cloud' (figure 31). That type of cloud gradually disappears again over the course of time as the water droplets in the cloud slowly evaporate.

▶ **figure 31**
fair weather clouds

If the air higher up in the atmosphere is relatively cold, bubbles of warm air can reach great heights. This gives you large clouds with a dark base (figure 32). Ice crystals then begin to form in the tops of the clouds. The ice crystals grow until they are too heavy to be carried along in the rising air. They then fall down out of the cloud.

If the air temperature lower down is above 0 °C, the ice crystals melt before they reach the ground. In that case they fall as rain. If the air temperature lower down is 0 °C or lower, the ice crystals reach the ground without melting. They then fall as snow.

Hail occurs in heavier showers because water droplets freeze onto ice particles. This only happens in clouds that have strong upward air currents. In that kind of airflow, the hailstones can keep growing because they keep on encountering more water droplets. When they finally do fall, they can often do a lot of damage.



▶ **figure 32**
rainclouds

Plus Air humidity

On a warm day, the sweat glands in your skin produce a lot of perspiration. Because the sweat then evaporates, you cool down and are less affected by the heat. If the air does not contain much water vapour the perspiration evaporates quickly. You do not end up feeling too hot. If the air does contain a lot of water vapour, the sweat evaporates more slowly. You then feel hot and sticky and your skin is clammy.

A hygrometer (figure 33) lets you measure the **air humidity**. The scale on this type of meter goes from 0% to 100%. A humidity value of 100% means that the air contains the maximum amount of water vapour. At a temperature of 29 °C, for instance, that is 30 grams of water per m^3. The weather is then very humid – 'muggy' or 'sticky'.

The air humidity is 50% if the air contains half the maximum amount of water vapour. At a temperature of 29 °C, this is 15 grams of water per m^3. Work it out: 15 : 30 = 0.5 = 50%.

Worked example
The temperature on a hot summer day is 29 °C. The air contains 12 grams of water vapour per m^3.
Calculate the humidity.

The maximum amount of water vapour the air can hold at 29 °C is 30 g per m^3.
The humidity is therefore 12 : 30 = 0.4 = 40%.

▲ figure 33
a hygrometer

Exercises

34 Copy and complete:
- **a** If it is ...... during the daytime, the air absorbs large quantities of water vapour.
- **b** Some of the water vapour condenses again at night because the air ....
- **c** The ...... that the water vapour begins to condense at is called the dew point.
- **d** The more water vapour the air contains, the ...... the dew point will be.

35 Cumulus clouds start out as rising 'bubbles' of warm air.
- **a** When does the water vapour in one of these air bubbles start to condense?
- **b** Why are you not able to see the bubble of warm air until then?

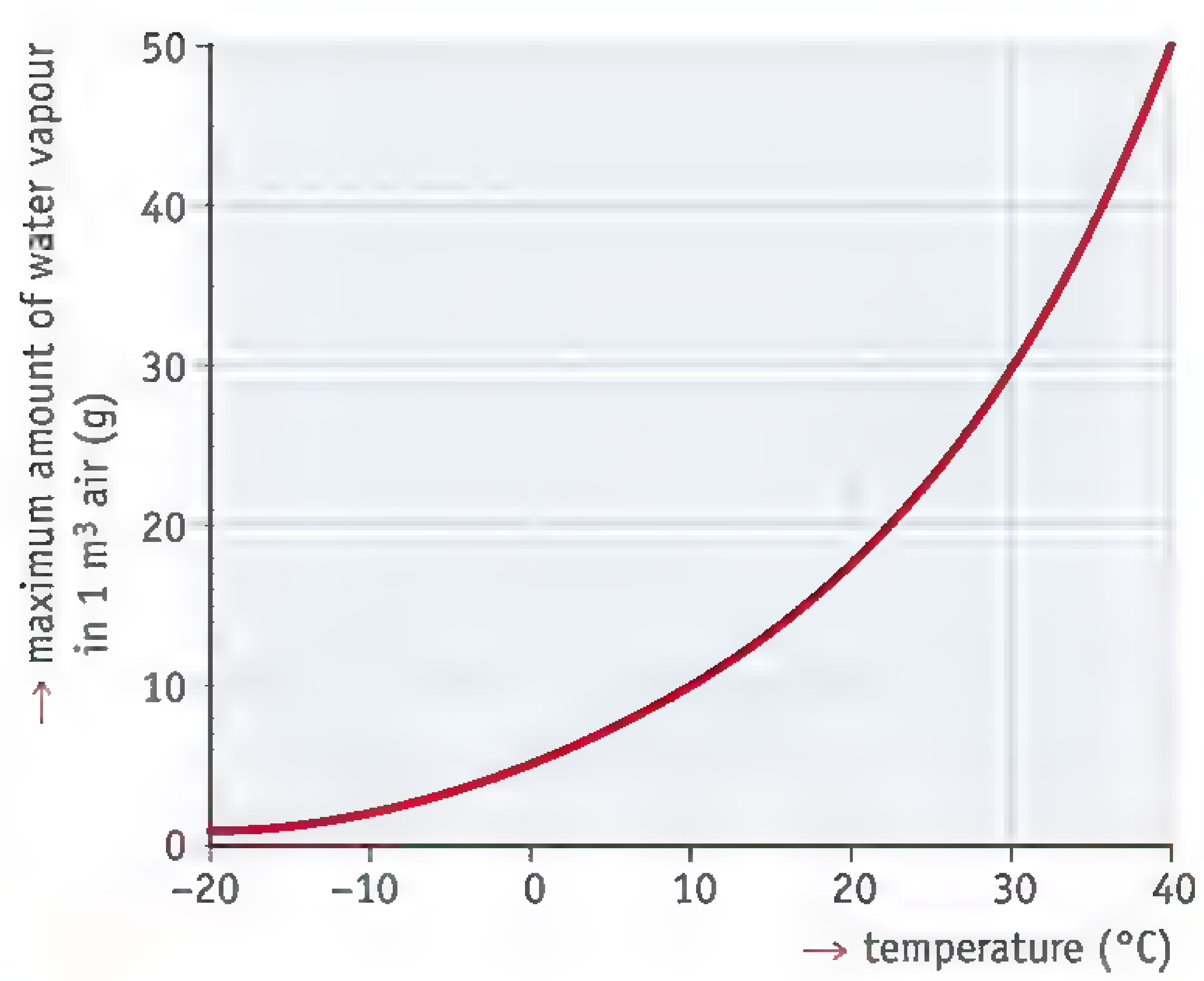
36 Read the weather report in figure 34.
- **a** Which phase transition causes cumulus clouds to be created?
- **b** Which phase transition causes the cloud cover to 'dissolve' again?
- **c** Why do cumulus clouds only appear during the course of the morning?
- **d** Why is it that ground mists can appear on clear summer nights in particular?

> The day will start with a clear blue sky. The first cumulus clouds will appear during the course of the morning. There will be sunny and cloudy periods in the afternoon, with temperatures of 22 to 23 °C. The clouds will have gone again by the evening. The night will be clear and localised patches of ground mist may occur.

▶ **figure 34**
a weather report

37 When it is warm during the day and cold at night, fog is often produced in the Netherlands. In desert areas it is always very hot during the day and it cools down a great deal at night. But you never get fog there. Give an explanation for this difference.

38 See figure 35.
At the end of a warm summer afternoon, the air outdoors contains 16 grams of water per cubic metre of air. The temperature is 24 °C.
- **a** Could this air hold even more water vapour? How can you see that in figure 35?
- **b** During the course of the evening and night the temperature decreases. At what temperature will the water vapour in the air start to condense?
- **c** The temperature falls, finally reaching 8 °C.
  How many grams of water vapour will condense for each cubic metre of air?



▶ **figure 35**
the relationship between the temperature and the maximum quantity of water vapour

***39** Meteorologists regularly release weather balloons that have a radiosonde and measuring instruments attached.
- **a** What measuring instruments do you need in order to determine the relationship between height and temperature?
- **b** What can you say about the chance of showers if the temperature decreases rapidly as the altitude increases?
- **c** What will the measured data look like on a sunny day with very little cloud cover?

***40** A bubble of warm air at 22 °C is rising. The dew point of this air is 8 °C. For every 100 metres it rises, the temperature of the air packet decreases by 0.5 °C.
- **a** At what temperature does the water vapour in the bubble of air start to condense?
- **b** When the water vapour begins to condense, a cumulus cloud starts to form.
  What height will the bottom of the cumulus cloud be at?

▲ **figure 36**
a cross-section of a large hailstone

41 Search the Internet for information about how hail occurs (figure 36).
- **a** What kind of weather conditions are needed for hailstones to be produced?
- **b** Why are hailstones often made up of various different layers of ice?
- **c** How large can hailstones get and what kinds of masses can they reach?
- **d** What is the difference between 'hard' hailstones and 'soft' or granular hail?

Plus Air humidity

42 When it is 25 °C outside that can be fine summer weather, or it can also be very 'sticky' or 'muggy'.
What determines whether you perceive the weather as pleasant or muggy?

43 On a hot summer day, the air contains 18 g of water vapour per m^3, when it could hold a maximum of 30 g/m^3.
Calculate the humidity.

44 The air temperature in a sauna can reach 80 °C. The people in the sauna do not find this unpleasant, though. Why is that?
- A The humidity is low, so their sweat evaporates quickly.
- B The humidity is low, so their sweat evaporates slowly.
- C The humidity is high, so their sweat evaporates quickly.
- D The humidity is high, so their sweat evaporates slowly.

Nova © Uitgeverij Malmberg

Experiments

Experiment 1 Air is not just nothing 15 min

Introduction
Air is not very conspicuous stuff. It is easy to forget that an empty glass is in fact full – of air.

Aim
This experiment shows you that air is not just emptiness, but a substance that takes up space.

Requirements
- balloon
- glass beaker
- block of cork or wood
- plastic measuring cylinder
- sheet of paper

Doing the experiment and writing it up
- Move your hand quickly back and forth through the air.

1 What do you feel? Why is that?

- Blow the balloon up a bit. Keep the end closed with your fingers.

2 Are you able to see that there is something – a quantity of a substance – in the balloon?

- Blow the balloon up a bit more.

3 What can you say about the quantity of substance inside the balloon? How do you know that?

- Squeeze the balloon.

4 What is giving the balloon its stiffness?

- Half fill a glass beaker with water. Put the cork or wooden block in the water so that it floats.
- Place the measuring cylinder upside down on the surface of the water, over the cork. Then push the measuring cylinder down (figure 37).

5 What happens to the cork or wooden block?

6 Why is that?

▲ figure 37
See what happens when you push the measuring cylinder down.

- Take everything out of the water.
- Push a wad of paper firmly to the bottom of the measuring cylinder, so that it will stay there when you turn the cylinder upside down.
- Turn the measuring cylinder upside down and push it right under the water.
- Take the measuring cylinder back out of the water and feel the wad of paper.

7 Why isn't the wad of paper wet?

Experiment 2 Air exerts pressure 15 min

Introduction
The layer of air around the Earth exerts pressure on everything on the planet's surface. You generally do not notice this much. This is why a variety of experiments have been thought up that can show you the effects of air pressure.

Aim
This experiment shows you one effect of the pressure that the atmosphere exerts.

Requirements
- test tube
- measuring cylinder
- cardboard
- scissors

Doing the experiment and writing it up
- Fill the test tube with water right to the top.
- Turn the test tube upside down over a sink.

1 What happens?

- Cut out a piece of cardboard that can completely cover the test tube's mouth.
- Fill the test tube with water right to the top.
- Place the piece of cardboard carefully on top of the test tube. Make sure that there is no air under the card.
- Hold the cardboard in place with a finger and turn the tube upside down above the sink.
- Let go of the paper, still keeping the test tube inverted.

2 What happens?

- Repeat this experiment with the measuring cylinder and a bigger piece of cardboard.

3 What happens now?
4 Think of an explanation for what you have observed.

Experiment 3 Air pressure and counter-pressure 20 minutes

Introduction
Glaziers use suction cups for lifting large and heavy window panes (figure 38). This makes use of the difference in pressure between the outside air and the counter-pressure inside the suction cup.

◀ figure 38 Lift the table up carefully a little.

Aim
You are going to investigate how suction cups work when used for lifting and hanging things.

Requirements
- two large suction cups
- mobile phone holder with a suction cup
- suction cup for a tea towel
- plate with a rough surface

Doing the experiment and writing it up
- Press the large suction cups against one another.
- Try to pull the suction cups apart.

1 What do you notice?

- Press the two large suction cups firmly onto a table.
- Try to lift the table up using the suction cups.

2 Explain how this kind of suction cup works. Use the terms 'air pressure' and 'counter-pressure'.

- Press the suction cup of the mobile phone holder against the table, without using the handle.
- Pull the suction cup loose.

3 What do you feel?

- Press the suction cup onto the table again, this time using the handle.
- Pull the suction cup loose.

4 What is different from the first time, when you did not use the handle?
5 Explain the purpose of the handle.

- Press the tea-towel suction cup onto the table. Pull it to check that it is properly attached.
- Lift up a small portion of the edge of the suction cup.
- Keep going until the suction cup comes loose.

6 Why does the suction cup suddenly come free at a given moment?

- Press the suction cup onto the plate with the rough surface.

7 Does the suction cup stay stuck in place? Explain why.

Experiment 4 Heating and cooling air 15 min

Introduction
Air that is being heated up or cooled down plays an important part in many weather effects.

Aim
In this experiment you are going to see what happens when the air in a balloon and a bottle is heated and cooled.

Requirements
- plastic water bottle
- balloon
- bowl of warm water
- bowl of ice water
- can of hot water

Doing the experiment and writing it up
- Blow the balloon up a bit and close the end by tying the neck tightly.
- Place the balloon in the warm water.

1 What can you see happening? Why is that?

- Place the balloon in the cold water.

2 What can you see happening? Why is that?

- Carefully pour about 10 cm of hot water into the plastic bottle.
- Then close the lid of the bottle and shake the bottle up and down vigorously for 15 seconds.
- Unscrew the lid from the bottle and pour the hot water out.
- Then screw the lid back onto the bottle again firmly.

3 Describe what you now see happening. Why is that?

4 Predict what will happen if you put the bottle into the cold water.

- See if your prediction was right.

5 Predict what will happen if you put the bottle into the warm water.

- See if your prediction was right.

Experiment 5 Convective flows in air 15 min

Introduction
If you heat up air at one place, the air there will expand. The hot air is 'lighter' than the cold air around it, as you will be able to tell.

Aim
In this experiment you see how heating air up at one place creates a convective airflow.

Requirements
- Bunsen burner
- tripod
- wire mesh
- string
- worksheet 4-2

Doing the experiment and writing it up
- Take worksheet 4-2. Cut out the spiral shape. Attach the string at A.
- Light the burner and set it to a small blue flame.
- Hold your hand 30 cm above the flame (figure 39). Be careful!

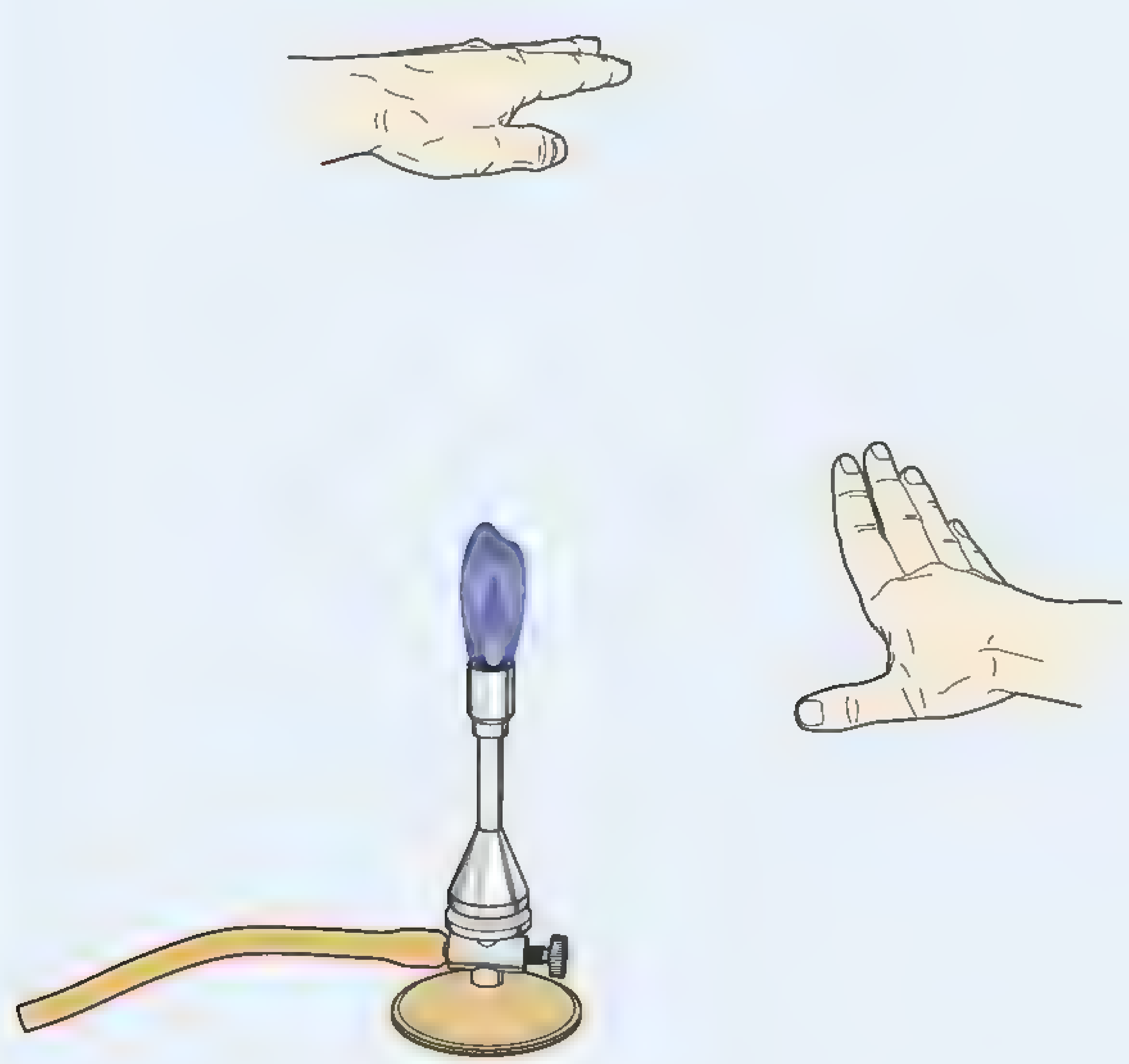
1 What do you feel?

- Now hold your hand 30 cm to one side of the flame (see figure 39). Be careful!

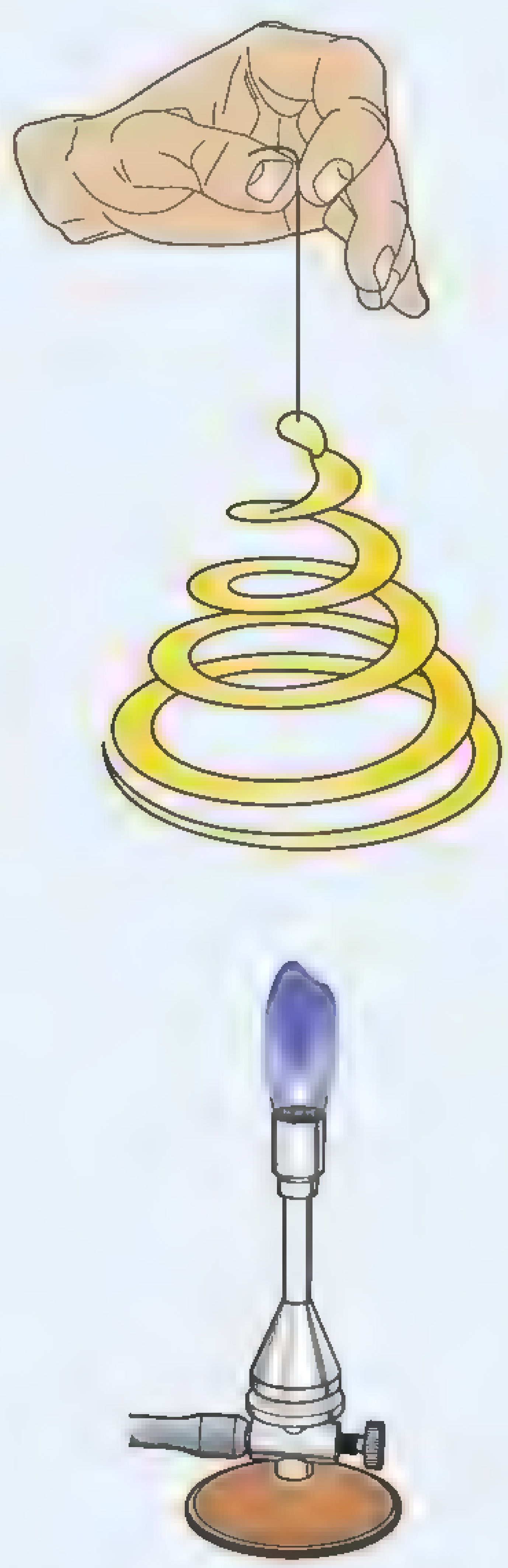
2 What do you feel now?
3 Try to explain the difference.

- Hang the spiral above the flame (figure 40). The distance between the flame and the bottom of the spiral must be at least 30 cm.

4 What do you see?
5 How can you explain that?



▲ figure 39
Keep the distances large enough in this experiment!



▲ figure 40
Suspend the spiral above the flame.

Experiment 6 Producing a design: the anemometer 90 min

Introduction
Imagine: your school is going to do a weather project in which the pupils will be gathering their own data about the weather. One of the weather data variables is the wind speed. You are given the assignment of designing a reliable anemometer for this. After various investigations, you decide not to try to come up with a new design all by yourself but to base your work on an existing design.

Aim
In this experiment, you will be designing, constructing and calibrating an anemometer. Your prototype must meet the following design requirements:

Design requirements
- The anemometer must be made of materials that are cheap or cost nothing. You can find ideas for this on the Internet.
- The anemometer rotates when the wind blows: the greater the number of revolutions per minute, the greater the wind speed.
- It must be easy to make measurements with the anemometer. Hint: convert the rotary motion into an electrical signal and then measure that.
- The anemometer must be sturdily constructed. It must be possible to make measurements with it without difficulty for at least two weeks, even with high winds.
- The anemometer must be calibrated: you must have checked that the wind speed can be measured reliably with it.

Requirements
For this experiment, you have to think up for yourself what equipment you will need. Discuss it if necessary with your teacher.

Doing the experiment and writing it up
- Search the Internet for information about anemometers that you can build yourself from cheap or free materials. Don't just look for 'anemometer' – try 'wind speed meter' and 'wind-speed meter' as well, and include terms such as 'home made' or 'DIY'.
- Think how you can carry out the experiment. What components will your meter contain, what items do you need and how can you calibrate the meter reliably?

1 Make a work plan for this experiment.

- The work plans will be discussed with the rest of the class in the next lesson. If necessary, you can make improvements to your own work plan after that.
- Construct the anemometer and calibrate it carefully.

2 Make a test report that includes:
 a a clear diagram showing how the anemometer is constructed;
 b the test you have carried out and the corresponding results;
 c any changes that you have made to the design.

Experiment 7 Carrying out research: insulating a beaker 30 min

Introduction
Imagine: if you fill a plastic beaker with hot chocolate or tea, you must not wait too long before drinking it. The beaker loses heat constantly, so the hot chocolate or tea keeps cooling down further. You wonder whether there might be a simple way of insulating the beaker, so that the contents stay hot for much longer.

Aim
You are going to investigate the best way of counteracting that heat loss. The question you are studying is:
What kind of insulation is most effective for insulating a beaker of hot water?
The idea is that the research groups will try out one method each. You will compare all the measured datasets against each other afterwards.

Requirements
For this experiment, you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up
- Think up different ways of insulating a plastic beaker: with a cardboard lid, with aluminium foil, with polystyrene, etc. Agree on the maximum quantity of material that each group is allowed to use.
- Design a measurement setup that can be used to gather the necessary measurements. What are you going to measure, and what items will you need for the experiment?
- Think about how you will be able to compare the measurement datasets fairly against each other afterwards. How can you determine whether one type of insulation is more effective than another?

1 Make a work plan for this research.

- The work plans will be discussed with the rest of the class in the next lesson. If necessary, you can make improvements to your own work plan after that.
- Then carry out the experiment. Collect all the data on the board afterwards. Then work together to draw your conclusions.

2 Note down all the measurements, including those of your classmates, in your exercise book.
3 Make a note of the conclusion you reached together, and why.

- Your teacher will tell you whether or not you have to write up a report on this experiment.

Test Yourself

You can also do questions 1 to 16 on the computer.

1 Richard screws the top off a full bottle of fizzy orange drink. He then sees gas bubbles appearing everywhere in the soft drink.
What gas are these bubbles made of?

2 Burning oil can be extinguished by covering the fire with a 'blanket' of foam.
What gas does the fire then lack?

3 The speed-skating track in Calgary is about 1000 metres above sea level. The skaters have to get used to competing at altitude, otherwise they might end up too short of breath, particularly in the longer-distance races.
This is because...
A they experience a shortage of oxygen.
B they are breathing in too much nitrogen.
C the air resistance is greater.
D they will be breathing more slowly.

4 Say whether the following statements are true or false.
a The gas flame of a Bunsen burner consumes not only natural gas but also oxygen.
b The air around you comprises 78% oxygen and 21% nitrogen.
c The pressure units hectopascals (hPa) and millibars (mbar) are equally large.
d The air pressure at sea level is about twice as great as at an altitude of 5.5 km.

5 The air measured at De Bilt (NL) on 16 December 2011 was 970 hPa.
An air pressure value of 970 hPa is ...
A extremely low.
B a little bit below average.
C a little bit above average.
D extremely high.

6 During a plane flight, Marie drinks three quarters of a plastic bottle of water. She screws the lid back onto the bottle and puts it back in her bag. After they land, she notices that the bottle has collapsed inwards quite a bit.
Select the right option.
During the final part of the flight, the pressure in the cabin *decreased / stayed the same / increased*, while the pressure in the bottle *decreased / stayed the same / increased*.

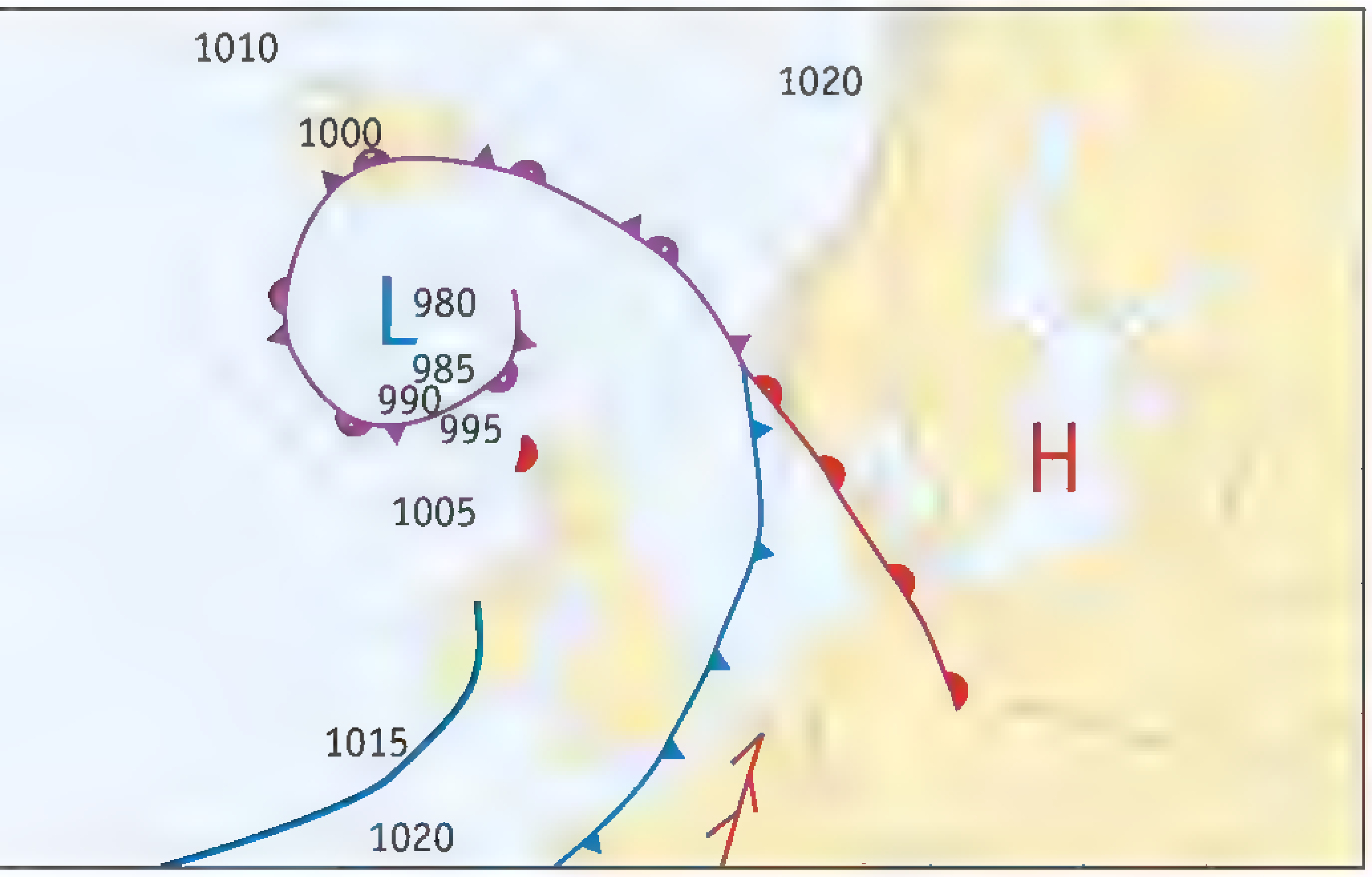
7 An altimeter in a plane is actually a modified barometer. The scale does not indicate the pressure but instead gives the height above sea level. To show the altitude reliably, the altimeter has to be adjusted to the air pressure at sea level. Suppose that the pilot accidentally enters 1002 hPa for the air pressure at sea level when it should really be 1012 hPa.
a Is the flight level then shown on the altimeter too high or too low?
b How big is the error, roughly: 10 metres, 100 metres or 1000 metres?

8 Weather balloons filled with helium are used for gathering meteorological information high in the atmosphere (figure 41). The balloons expand a great deal as they rise, until they finally tear. The radiosonde that gathers and transmits the weather data then comes back down on a parachute.
a Adrian says, "As the balloon rises, the air in it gets warmer. That is why the balloon keeps expanding."
Is this statement correct?
b Ethan says, "The balloon expands as it rises. This is because the air pressure outside the balloon is continuously falling."
Is this statement correct?

◀ **figure 41**
a meteorological balloon as it starts off

9 Select the correct options.
a The pressure of the air in your lungs is on average *higher than / the same as / less than* atmospheric pressure.
b To inhale, you make the volume of your lungs *larger / smaller*. The pressure of the air in your lungs is then a little *higher / lower* than atmospheric pressure. This makes air flow *into / out of* your lungs.
b To exhale, you make the volume of your lungs *larger / smaller*. The pressure of the air in your lungs is then a little *higher / lower* than atmospheric pressure. This makes air flow *into / out of* your lungs.

10 In figure 42 you can see a fragment of the Dutch weather service's chart for 3 July 2005.
What will the weather probably have been like in Iceland on that day?
A A severe northerly or northwesterly gale with a lot of rain.
B A severe southerly or southwesterly gale with a lot of rain.
C A gentle breeze from the north or northwest; no precipitation.
D A gentle breeze from the south or southwest; no precipitation.



▲ figure 42
a fragment of a weather map

11 You see lines drawn on weather charts with numbers such as 980 or 1020 next to them.
a What are these numbered lines called?
b What variable are these lines referring to?
c What units does the weather chart use for expressing this variable?

12 Copy and complete:
a Insulation materials such as glass wool and polystyrene get their insulating effect from the ...... that is in them.
b The ...... is efficiently 'trapped' in the insulation material so that it cannot be blown away by the ......
c The thicker the layer of insulating material, the ...... heat disappears to the outside through the insulation.

13 What is the term for an airflow that is created by a localized temperature difference?

14 Copy and fill in the correct variables:
You can choose between *density / mass / volume*.
When a bubble of warm air expands, the ...... of the air remains the same, but the ...... increases. The ...... of the air decreases as a result.

15 The hot gases that are emitted from a factory chimney often include a large proportion of water vapour (figure 43).
Which phase transition is responsible for:
a the white mist that you often see appearing a little way above the chimney?
b the same mist disappearing again without a trace some distance further away?


▶ figure 43
A factory chimney emitting water vapour.

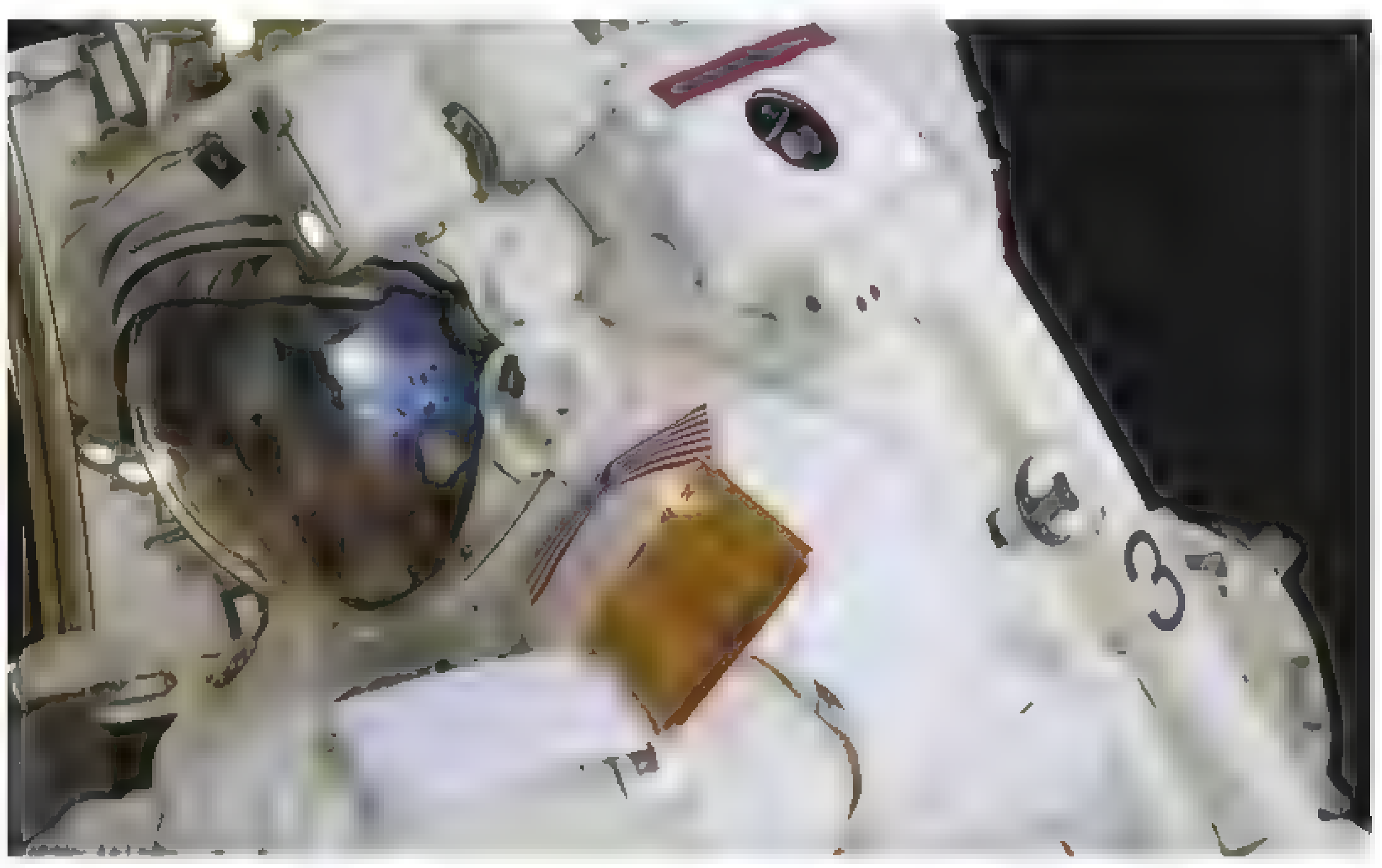
16 Say whether the following statements are true or false.

- **a** The water vapour in air starts to condense when the temperature rises above the dew point.
- **b** The greater the quantity of water vapour per cubic metre of air, the higher the dew point.
- **c** Air at 30 °C can hold much less water vapour than air at 0 °C (expressed in g/m^3).
- **d** The more the air cools down at night, the greater the chance that dew will appear.

17 Martin has put 100 mL water in a glass beaker. He then heats the water with a Bunsen burner.

- **a** Which two gases are produced by the combustion of natural gas?
- **b** Martin notices that the glass beaker mists over almost immediately.
  Which of the two gases is condensing against the cold glass beaker?
- **c** Why does that condensation then disappear again quickly?

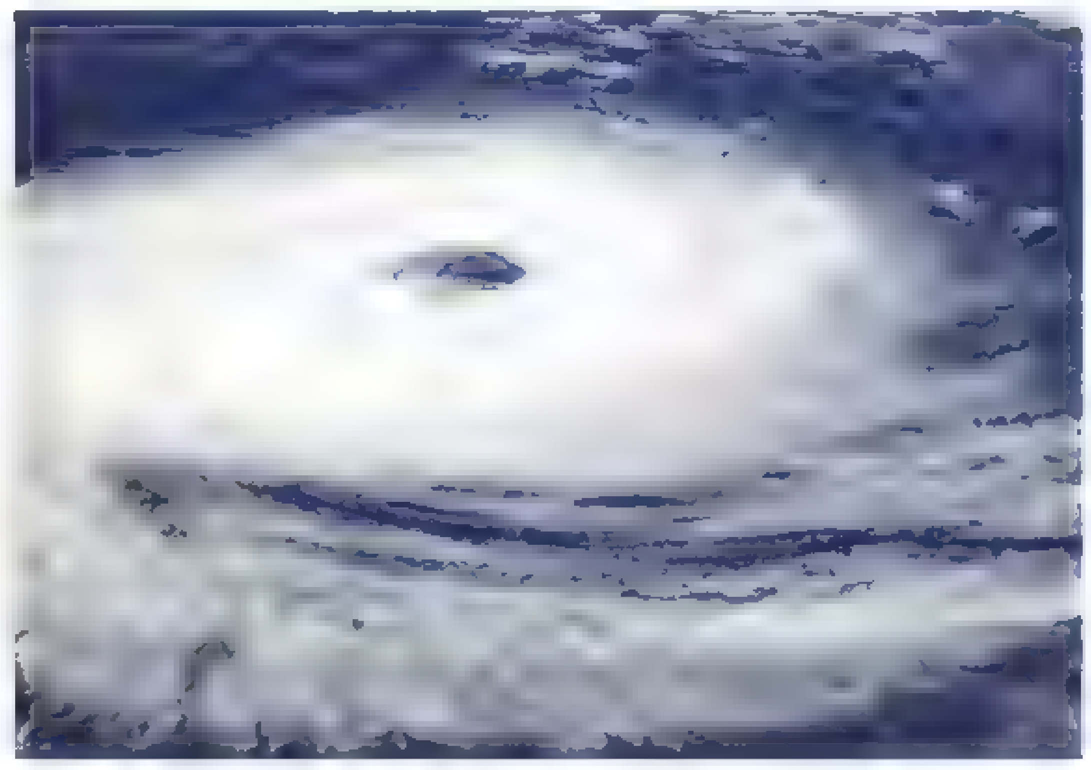
18 Astronauts put on a special spacesuit before a spacewalk (figure 44). These spacesuits are full of air that keeps the astronaut's body pressurized. Explain why a pressure suit like this is an absolute necessity.



▲ **figure 44**
NASA astronaut Sunita Williams during a spacewalk.

19 In figure 45 you can see a satellite photo of hurricane Yasi in Australia.

- **a** How can you see that the hurricane developed around a low pressure area?
- **b** How can you see that it is a photo of the southern hemisphere?
- **c** What can you say about the distances between the isobars in the storm area?



◀ **figure 45**
a satellite photo of hurricane Yasi

20 Thunderstorms are only produced when the conditions in the atmosphere are suitable.
You can read more about that in the report in figure 46.

- **a** Under which conditions is the chance of thunderstorms very high?
- **b** Under those conditions, will a bubble of warm air:
  - rise upwards quickly or slowly?
  - stop moving relatively quickly or continue to a great height?

Thunderstorms create a spectacle

A number of violent thunderstorms created problems throughout the Netherlands yesterday. The storms developed because of a strikingly large difference between the temperatures at ground level and high up in the atmosphere. Temperatures of –22 to –25 degrees were measured at an altitude of 5.5 kilometres, whereas a thermometer at eye level registered +20 degrees.

▶ **figure 46**
a news report

The weather on Mars

The air is virtually cloudless, pale pink and with just a faint veil of cloud. The sun is high in the sky, but has surprisingly little effect. And it is not very warm either, at 5 °C.The air pressure today is 847 Pa, an exceptionally low value by Earth standards. The landscape is dusty and bone dry – it never rains here – and the place is utterly deserted except for a bizarre six-wheeled robot. Date:Sol 108.Location: the Gale crater on Mars.

You do not actually have to have been to Mars to be able to draw conclusions about it. This is thanks to a whole series of unmanned probes that the Americans and Russians have sent to our neighbouring planet. From 2004 onwards there were actually two robot vehicles driving around on Mars: the rovers Spirit and Opportunity. Spirit stopped working in 2010, but at the time this was written (winter 2012), Opportunity was still active, with more than 35 km on the clock.

The vehicle fleet on Mars was expanded on 6 August 2012 with a third rover, the six-wheeled vehicle *Curiosity*. *Curiosity* is about the size and weight of a mid-range car. The price is a different matter altogether: the price tag for the project is about 2.5 billion euros. But you do get quite a bit in return: a capable and robust research vehicle, which has not only a well-equipped laboratory but also its own weather station.

"Today, the wheels of *Curiosity* have begun to blaze the trail for human footprints on Mars."

The weather forecast for Mars

One of *Curiosity's* tasks is to study how habitable Mars is. NASA, the organisation behind the *Curiosity* projects, wants to put people on Mars one day – and, if you want to do that, the first thing to do is make sure you know what to expect. *Curiosity* is therefore going to be studying the conditions on Mars, in preparation for a manned expedition later in the 21st century. "Today, the wheels of *Curiosity* have begun to blaze the trail for human footprints on Mars," twittered the head NASA administrator after *Curiosity* landed.

Future Mars travellers will for example want to know what kind of weather they can expect. *Curiosity* therefore has a complete weather station on board: the Rover Environmental Monitoring Station (REMS). The instruments of the REMS measure the air pressure, the air temperature, the wind speed, the humidity and the UV radiation intensity. The REMS team puts a weather report with the local weather data online every Martian day or 'sol' (24 hours, 39 minutes and 35 seconds – just a bit longer than a day on Earth).

Extremely cold nights

Not that the weather report actually sounds very attractive. It is much colder on Mars than it is on Earth, for example, with large temperature differences between day and night. At the place where *Curiosity* landed, a little to the south of the equator, the temperatures are tolerable during the daytime. It was spring there during the first month or so after the landing. The midday temperature then was about 0 °C,

Types of Mars probes

Space aficionados categorise the Mars explorers into orbiters, landers and rovers.

- Landers make a soft touchdown on the Martian surface and then remain in that one location. One famous example is the Viking programme of the 1970s, with landers that investigated whether life was present on Mars.
- Orbiters describe a more or less circular path or 'orbit' around the planet, just like weather satellites orbit the Earth. As they circle the planet, they take photographs of the surface or probe it with radar.
- Rovers are the robot vehicles that drive around on the Martian surface, looking for interesting materials to investigate. The rover Curiosity has a robot arm that it can use to scoop up soil samples for further investigations.

Nova © Uitgeverij Malmberg

with extremes of up to 5 or 6 °C, and it will undoubtedly be even warmer in the summer.

But the temperature falls rapidly when the Sun goes down. Because the Martian atmosphere is so thin and tenuous, it is not easy for the planet to retain its heat. This means that it gets extremely cold there at night. The weather station on *Curiosity* recorded night-time temperatures of about −70 °C – and that was close to the equator! Compare that against the lowest temperature ever measured in the Netherlands, which was 'only' −27.4 °C.
But even though it is not intolerably cold during the daytime, there's no question of going out for a nice stroll (in a thick jacket if needed). Humans could not live in the atmosphere on Mars, first of all because of its composition: 95% carbon dioxide, 3% nitrogen, 1.6% argon and only traces of oxygen and water vapour. On top of that, the atmosphere is extremely thin – much more tenuous than at the highest mountain peaks on Earth. People could only survive on Mars in well-sealed accommodation with an Earth-like atmosphere. For trips outside, they will need to put on a Mars spacesuit with a life support system.

No liquid water

Because the atmosphere is so thin, the air pressure on Mars is far lower than on Earth. At an average altitude the air pressure averages just 7.5 mbar, which is 0.6% of the average air pressure at sea level on Earth. (There are no seas on Mars and so there is no sea level. Instead of that, the average height of the land is used as the reference height for air pressure measurements.)

The low air pressure means that liquid water could only exist briefly on Mars. This is because water would start boiling at once at such low air pressures. You get the same effect if you put a glass of water under a glass bell jar and then pump the air out. The water will then also start boiling 'spontaneously' as the air pressure drops. The boiling water evaporates quickly and will therefore disappear very quickly.

"Mars is therefore drier than the driest deserts on Earth."

Nova © Uitgeverij Malmberg

Mars is therefore drier than the driest deserts on Earth. There are no oceans, lakes or rivers – or at least there have not been any for a very long time. The Martian soil is bone dry and covered with a thick layer of dust. The lack of water would be a problem if people want to stay on Mars for longer periods. Cultivating your own food, for example, would be very difficult if all the necessary water had to be brought from Earth.

To Mars... for ever

According to the British astronomer Martin Rees, it is "only a question of time" before people are walking around on Mars. "It's stupid to suggest that mass emigration into space could be a solution for the problems on Earth," he says in an interview with the British newspaper, The Times, "but I do believe – and hope – that some people who have already been born may indeed be able to walk on the surface of Mars in future."

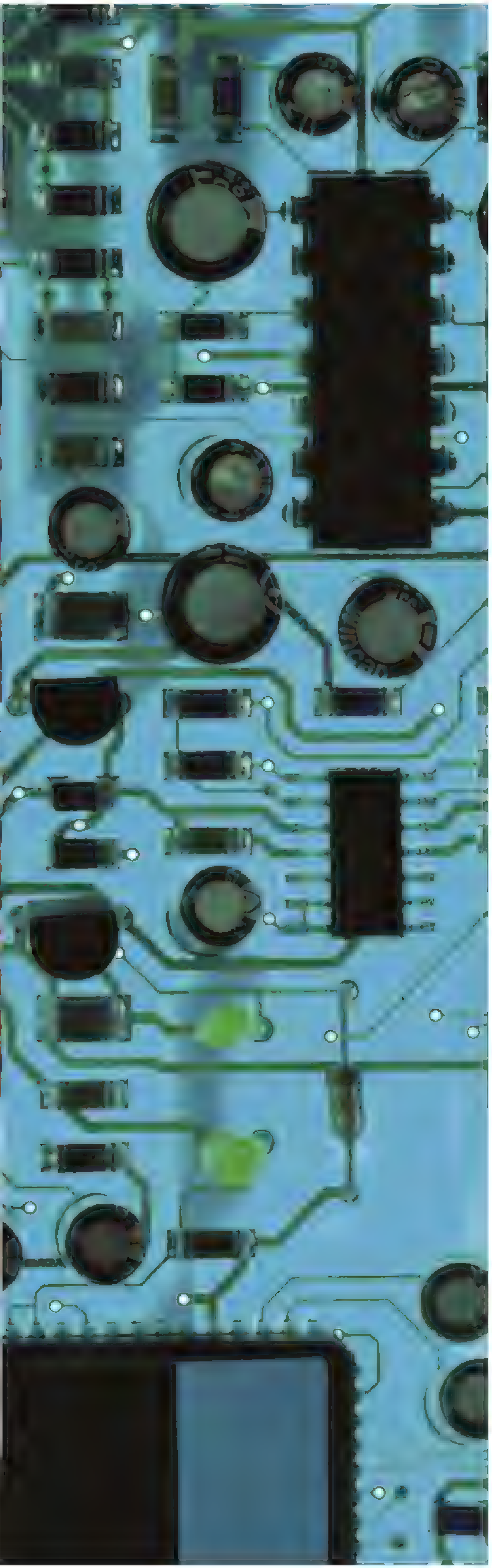
Maybe Martin Rees is being too optimistic. But maybe not. The picture above is an artist's impression of the colony that the American rocket builder Elon Musk wants to found on Mars. He wants to offer Mars colonists a one-way ticket for half a million dollars per person – without any way of coming back, because the project would then be too expensive. An attractive proposition? Thanks to *Curiosity*, you already know one thing: don't go doing it for the weather!

Exercises

1 Explain why:
- a there are big differences between daytime and nighttime temperatures on Mars.
- b it would be impossible for humans to stay alive in the Martian atmosphere.
- c liquid water cannot be found anywhere on the surface of Mars.

2 In the Gale crater, where the *Curiosity* rover is driving around, the average air pressure is a little higher than the 'standard pressure'.
- a What definition is used on Earth to define the standard reference altitude?
- b Why did a different definition have to be thought up for Mars?
- c What might be the explanation for the higher air pressure in the Gale crater?

*3 Search the Internet for information about the Martian polar ice caps.
- a What kind of substance is the 'dry ice' that is deposited at the north and south poles during the winters?
- b Why is the ice cap at the south pole much bigger than the ice cap at the north pole?
- c Why does the air pressure on Mars rise significantly as the southern ice cap shrinks?



5

Electricity

Portable devices

An electrical device that runs on batteries can be taken with you and used wherever you want. The radius of action is not limited by the length of the cable – as long as you don't forget to recharge or change the batteries in good time.

1 Making an electrical circuit

▲ figure 1
Making an electric circuit.

You will find all sorts of devices at home that run on electricity. Devices that need a lot of electrical energy, such as a vacuum cleaner or a kettle, have to be plugged into the mains. Other devices obtain the electrical energy they need from batteries.

A closed electrical circuit

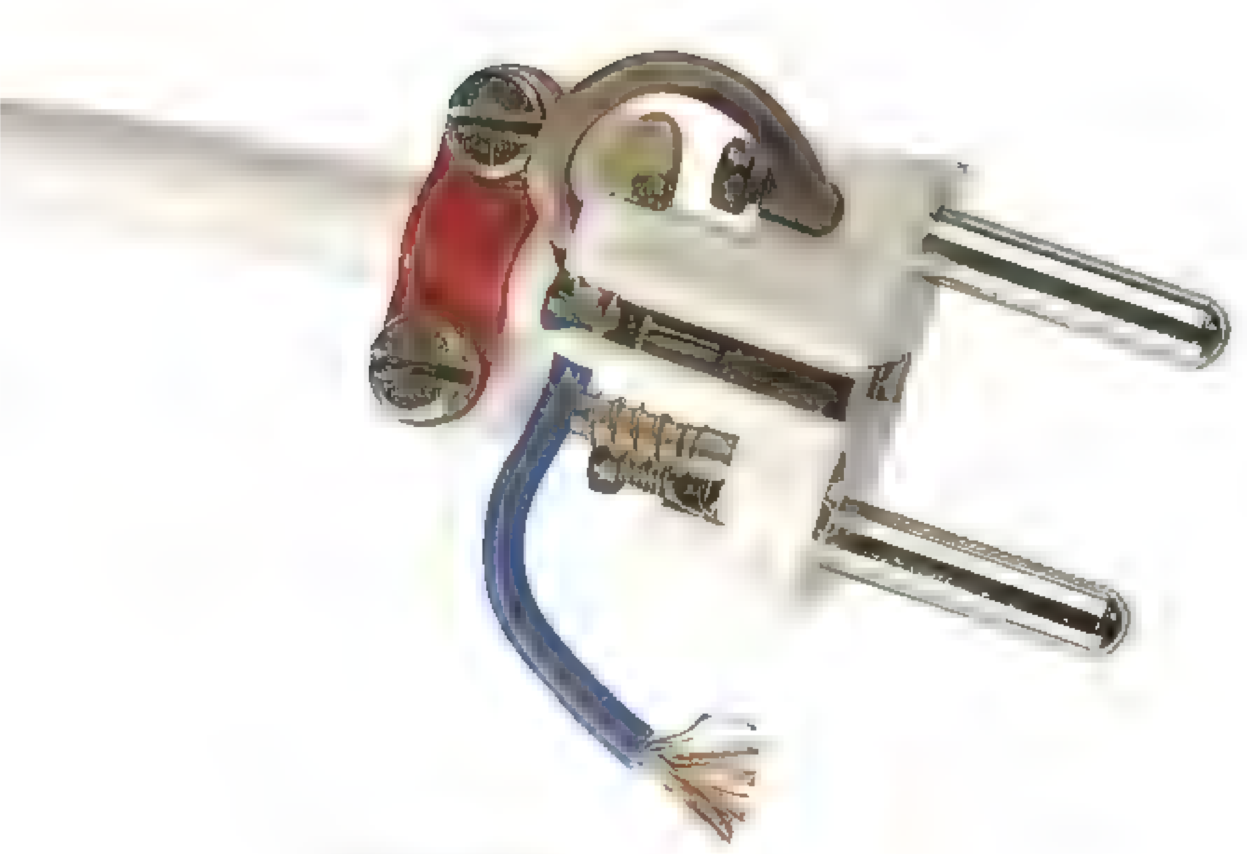
To light a bulb, you need to pass an electric current through it. This is only possible if you make a closed **circuit.** This could, for instance, go from one terminal of a battery, through the bulb and back to the other side of the battery (figure 1).

When the bulb is lit, it is using **electrical energy.** The energy is supplied by the battery. The electrical wires transport the electrical energy from the battery to the bulb. This is how an electrical circuit is formed. You will always find:
- a **voltage source** that supplies the electrical energy;
- **connections** that carry the electrical energy;
- one or more **devices** that consume the electrical energy.

A battery is only capable of supplying a limited amount of electrical energy. When that energy has been used up, we say that the battery is 'flat'. A rechargeable battery can be charged up again so that it can supply electrical energy once more. This cannot be done with a non-rechargeable battery. When they are flat, you have to dispose of them with the small chemical waste items.

Insulating and conducting substances Experiment 1

There are various ways of connecting the components of a circuit together. For experiments with electricity you use connecting leads. The electrical current flows through the copper wire that makes up the core of the lead. The outside of the lead is plastic. Electrical currents do not flow through the plastic (figure 2).

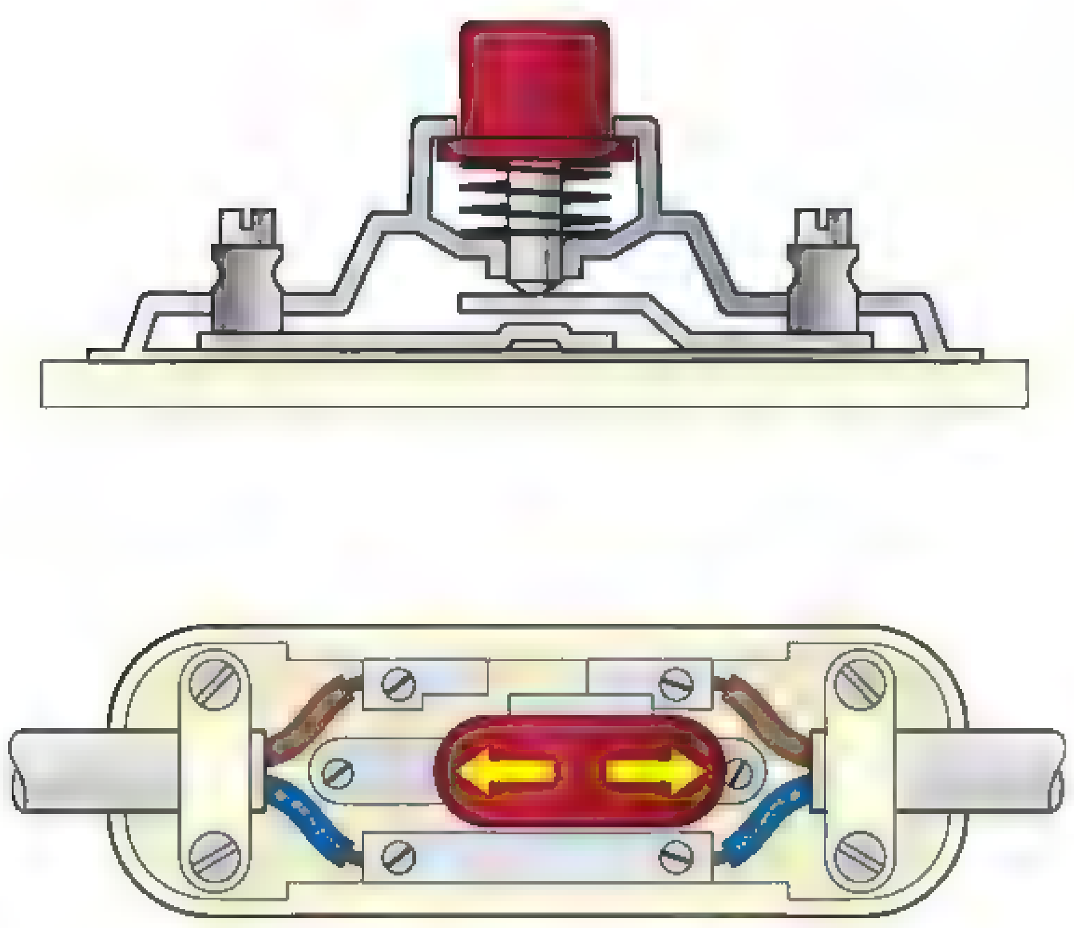


▲ figure 2
A plug and an electrical wire consist of conductors and insulators.

Substances that electrical currents can flow through easily are called **conductors.** All metals are conductors, but some metals conduct better than others. Copper and aluminium, for example, are better conductors than iron and lead. Carbon is a conductor too, even though it is not a metal.

Substances that do not allow electrical currents to pass through them (or only very poorly) are called **insulators.** Examples are rubber, glass and most plastics. If a solid substance is not a metal, it will almost always be an insulator. Air is also a good insulator.

In a closed electrical circuit, the current flows through the conducting parts of the wires, bulbs or other devices. You can use a **switch** to turn the current on and off (figure 3). When you switch the current on, two conducting parts of the switch come into contact. This closes the circuit. When you switch the current off, there is no longer a conducting connection.



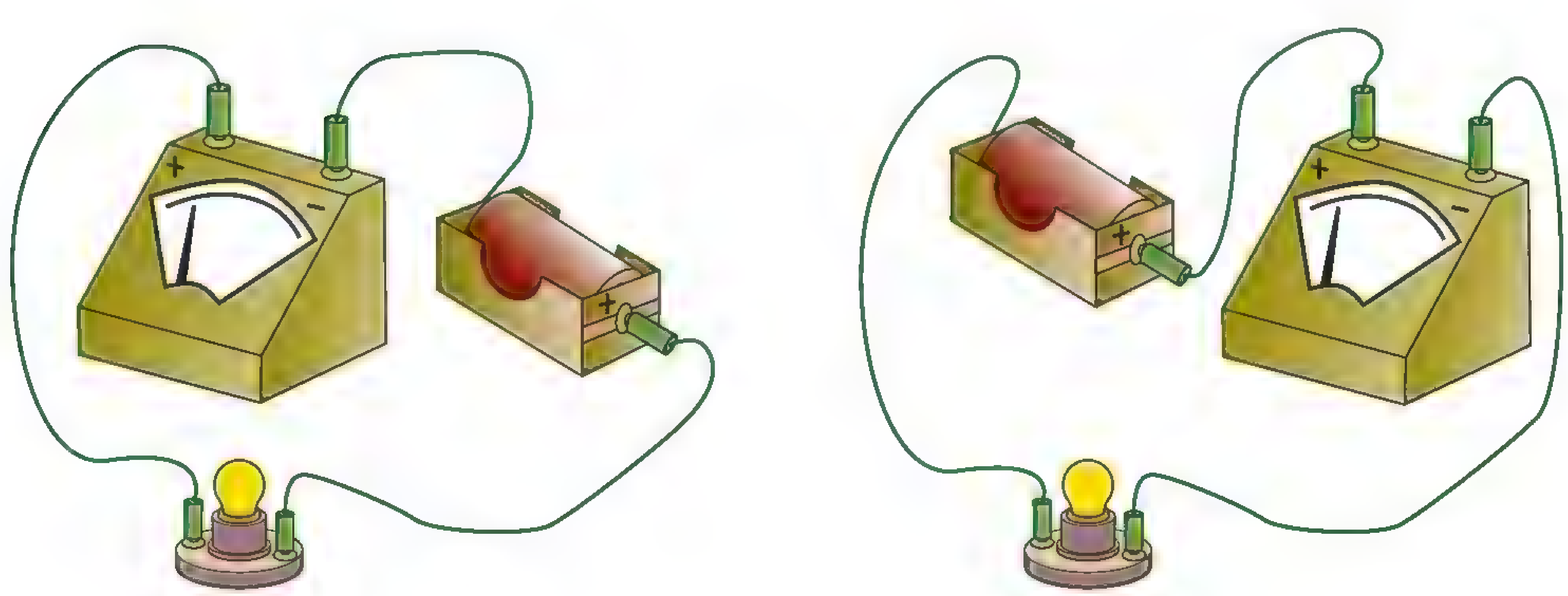
▲ figure 3
two types of switches

Measuring current   Experiment 2

When you connect a bulb to a battery, a current flows through the bulb. An electrical current consists of small particles that move through the conducting materials. We say that the current flows 'from positive to negative': from the positive terminal of the battery, through the bulb and back to the negative terminal.

You can use an **ammeter** to measure how much current is flowing through a circuit. The unit of measurement for current, the **current strength,** is the ampere (A), often also called the amp. The name 'ammeter' is a shortened form of 'ampere meter' or 'amp meter'. Small currents are often measure in milliamps (mA).

It does not matter where you put the ammeter in the circuit: it can be to the left or the right of the bulb. This is because the current is the same at all points along the circuit (figure 4).



▶ figure 4
two ways of measuring the size of the current

▶ figure 5
a close-up of a LED

Plus LEDs

A **LED** is a type of bulb that is used in all kinds of lighting. One characteristic of a LED is that current can only flow through it in one direction. If you try to connect it the other way round, no current flows and the LED does not give off any light. You therefore have to be careful to connect LEDs the right way round: the longest connecting leg has to be connected to the positive side of the battery (figure 5).

LED stands for 'light-emitting diode'. That is the name of the small electronic component that actually produces the light. If you have a LED with a clear plastic sheath, you can see the actual diode if you look carefully. The plastic sheath protects the LED and the connecting wires. The rounded top of the LED also helps concentrate the light from the LED into a beam.

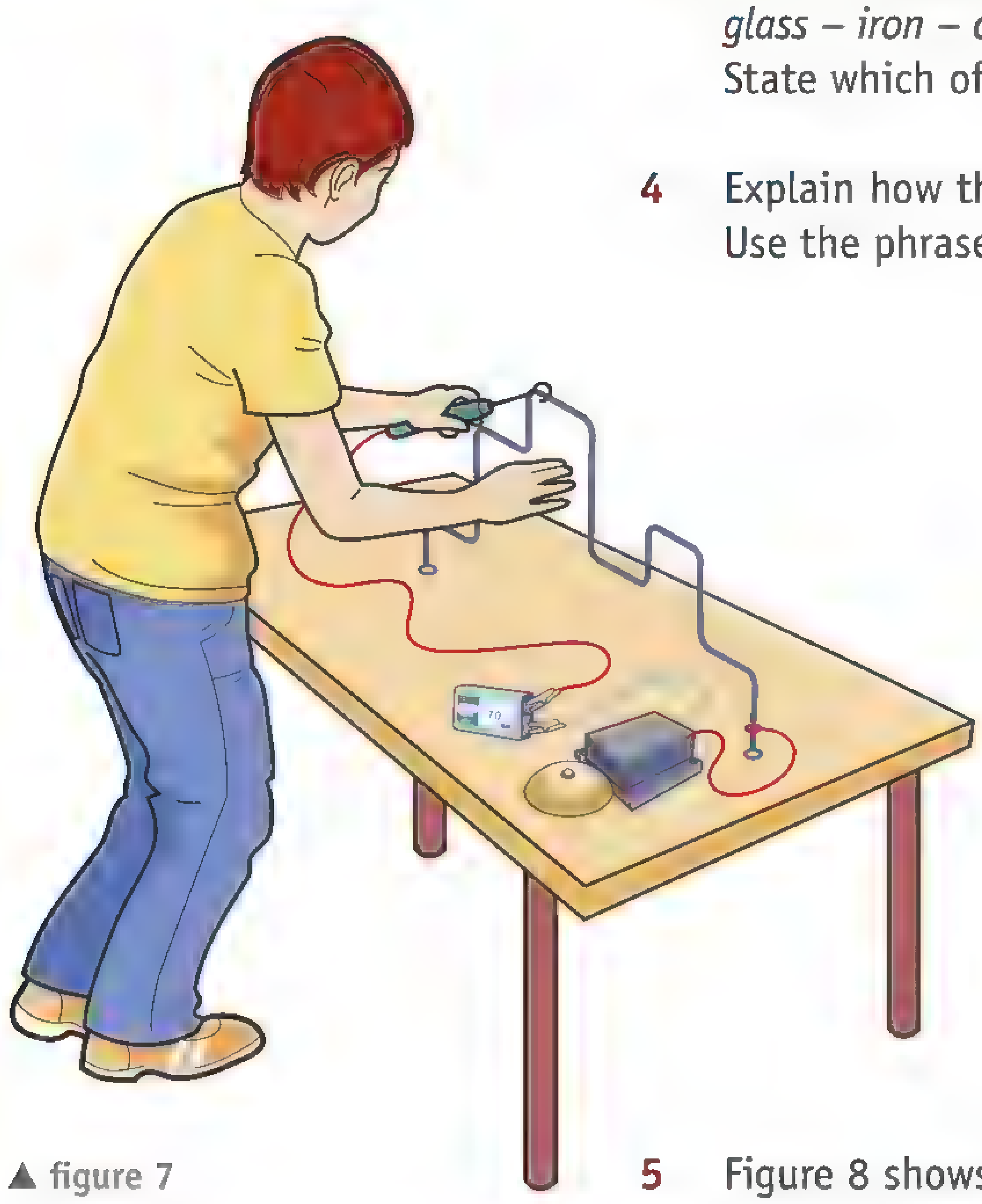
Red LEDs are used a lot for rear bicycle lights, even though they are more expensive than incandescent bulbs (figure 6). The advantage of LEDs is that they use electrical energy very efficiently: they give much more light for the same input of electrical energy. On top of that, LEDs last much longer than incandescent bulbs and they are also more shock-resistant.

◀ figure 6
a rear light for a bicycle with five LEDs

Exercises

1 Answer the questions below.
- **a** What do you have to do in order to light a small bulb (such as for a bicycle) using a battery?
- **b** Which group of substances are all good conductors of electricity?
- **c** What do you call substances that do not allow electrical currents to pass through them (or only very poorly)?
- **d** What component can you use to turn the current in an electrical circuit on and off?

2 Copy and complete:
- **a** An electrical current consists of small ...... that flow through ...... materials.
- **b** You can use an ...... to measure the current in a circuit.
- **c** The magnitude of the current is measured in ......, abbreviated to the letter ....



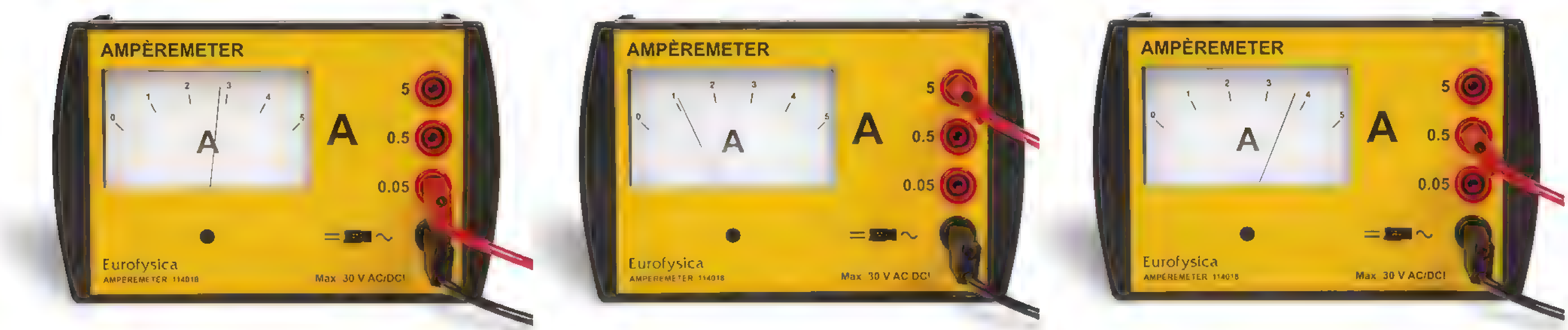
▲ figure 7
If your hand isn't steady, the bell will ring.

3 Seven substances are listed below:
glass – iron – carbon – copper – air – plastic – rubber
State which of these substances are conductors.

4 Explain how the game in figure 7 works.
Use the phrases 'open circuit' and 'closed circuit' in your explanation.

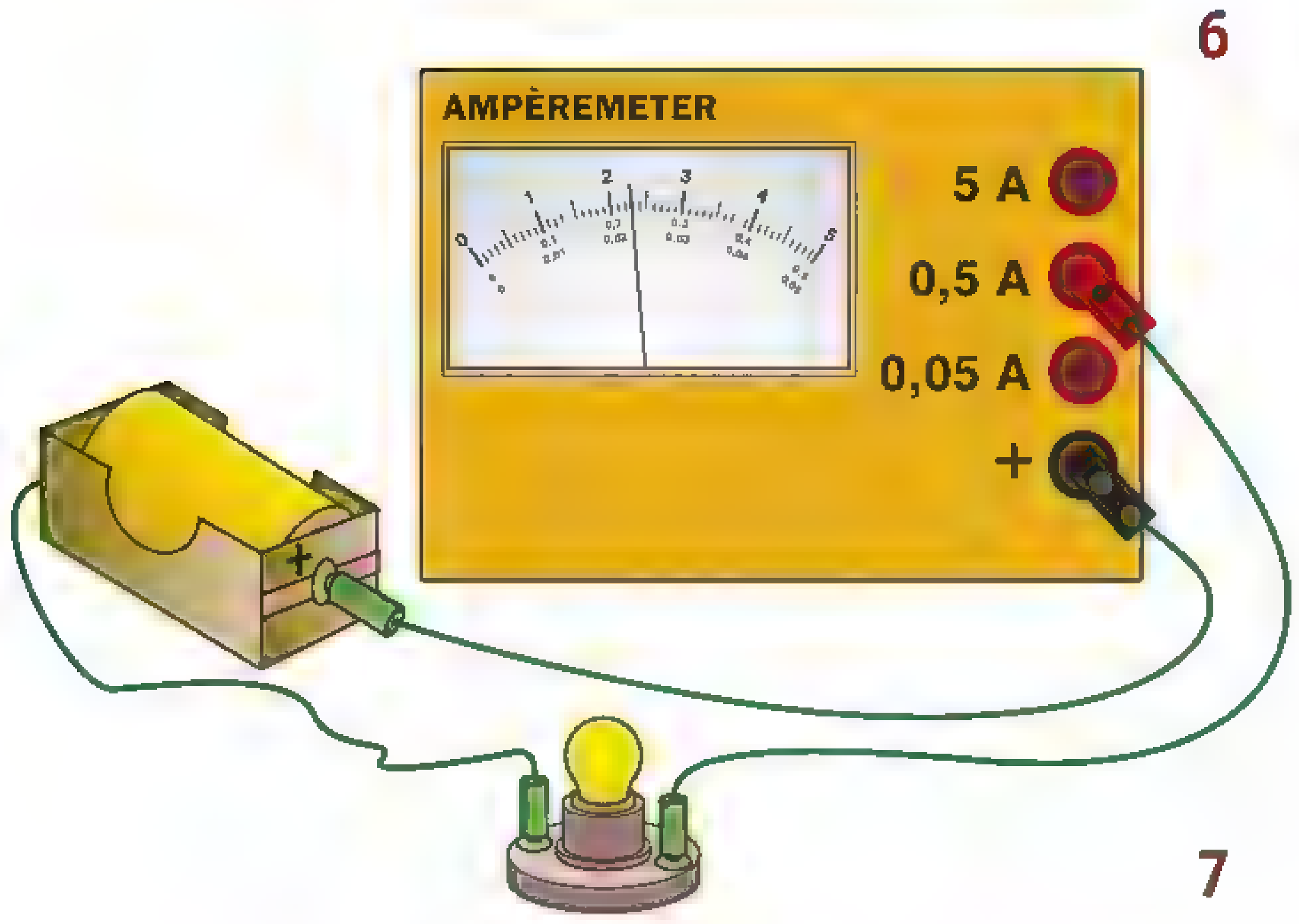
5 Figure 8 shows you three photos of an ammeter. Learning how to read an ammeter is covered in 'Skills 8'.
Read off the currents that the three meters are showing and write them down.

If you need more practice, go to the V-trainer.



▲ figure 8
What currents are the three ammeters showing?

Nova © Uitgeverij Malmberg



▲ figure 9
Rachel's experimental setup

6 Rachel measures the current between the positive terminal of a battery and a bulb (figure 9).

a What current is the ammeter reading?

b Rachel then measures the current between the bulb and the negative terminal of the battery.
What can you say about the current that she measures now?
A It is greater than what she just measured for point a.
B It is the same size as what she just measured for point a.
C It is smaller than what she just measured for point a.

7 Copy and complete:

a 37 mA	= ...... A	**f** 950 mA	= ...... A
b 452 mA	= ...... A	**g** 0.072 A	= ...... mA
c 0.250 A	= ...... mA	**h** 0.008 A	= ...... mA
d 0.032 A	= ...... mA	**i** 82 mA	= ...... A
e 3 mA	= ...... A	**j** 0.125 A	= ...... mA

If you need more practice, go to the V-trainer.

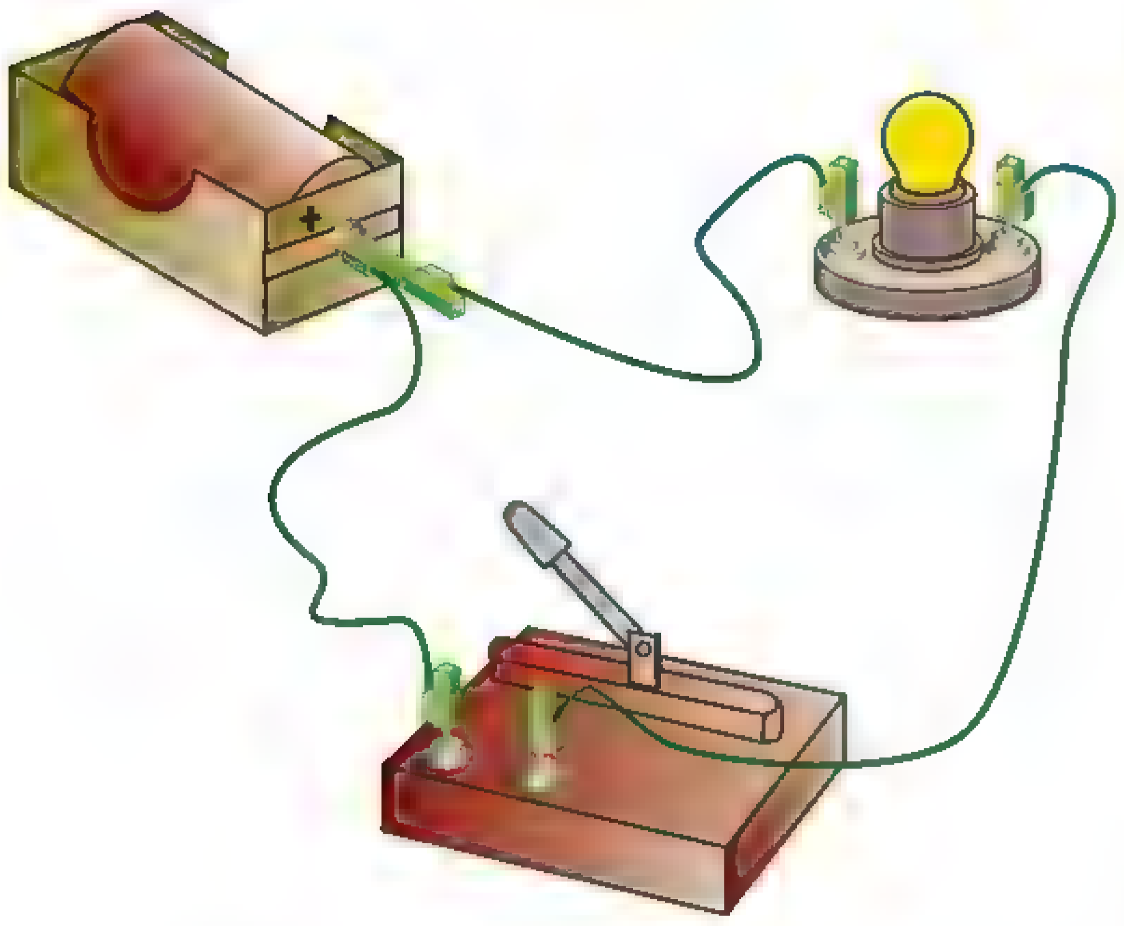
8 When you turn a light switch to the OFF position, a circuit is broken. There is then only air between the conducting parts of the switch. Explain how this lets you conclude whether air is a conductor or an insulator.

9 Luke wants to investigate whether tap water conducts electricity. Explain how he can do an experiment to find this out. Make a sketch of his experimental setup.

10 Flora finds an article on a website about how you can easily make your own door alarm. The guide is shown in figure 10.
Explain how the circuit works.

***11** Figure 11 shows you a circuit with a bulb, a battery and a switch. The switch is closed.
Explain why the bulb is not lit.

▼ figure 10
Making your own burglar alarm.



▲ figure 11
Why is the bulb not lit?

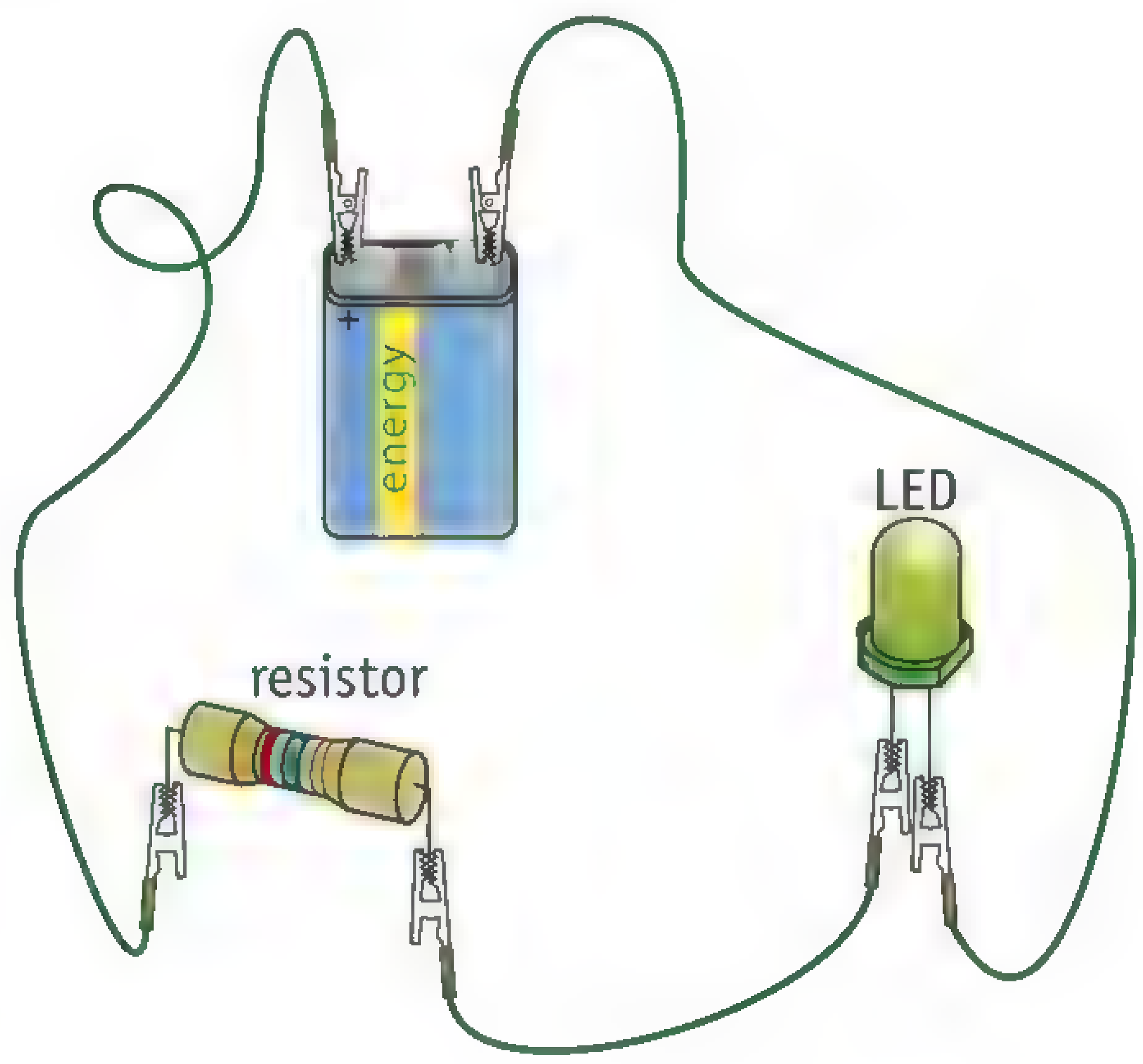
Plus LEDs

12 Beth has connected a LED up to a battery (figure 12). The LED is not lit. Beth is sure that there is nothing wrong with either the battery or the LED and that the wires are securely attached.

a What is probably wrong?

b Beth then makes a circuit with two LEDs. When she connects up the battery, one of the LEDs lights up. When she connects the battery the other way round, the other LED lights up.
Draw the circuit that Beth has made.

***13** Ben has bought a pocket torch with LED bulbs. The pocket torch gives about as much light as an old-fashioned flashlight with a small incandescent bulb, but it is more expensive. Nevertheless, Ben will be better off in the longer term with his modern pocket torch.
Explain why.



▶ figure 12
Beth's circuit

2 Voltage sources

To create a circuit, you need a voltage source that delivers the required electrical energy. Commonly used voltage sources are batteries and dynamos. The panels with solar cells that you often see on roofs are also voltage sources.

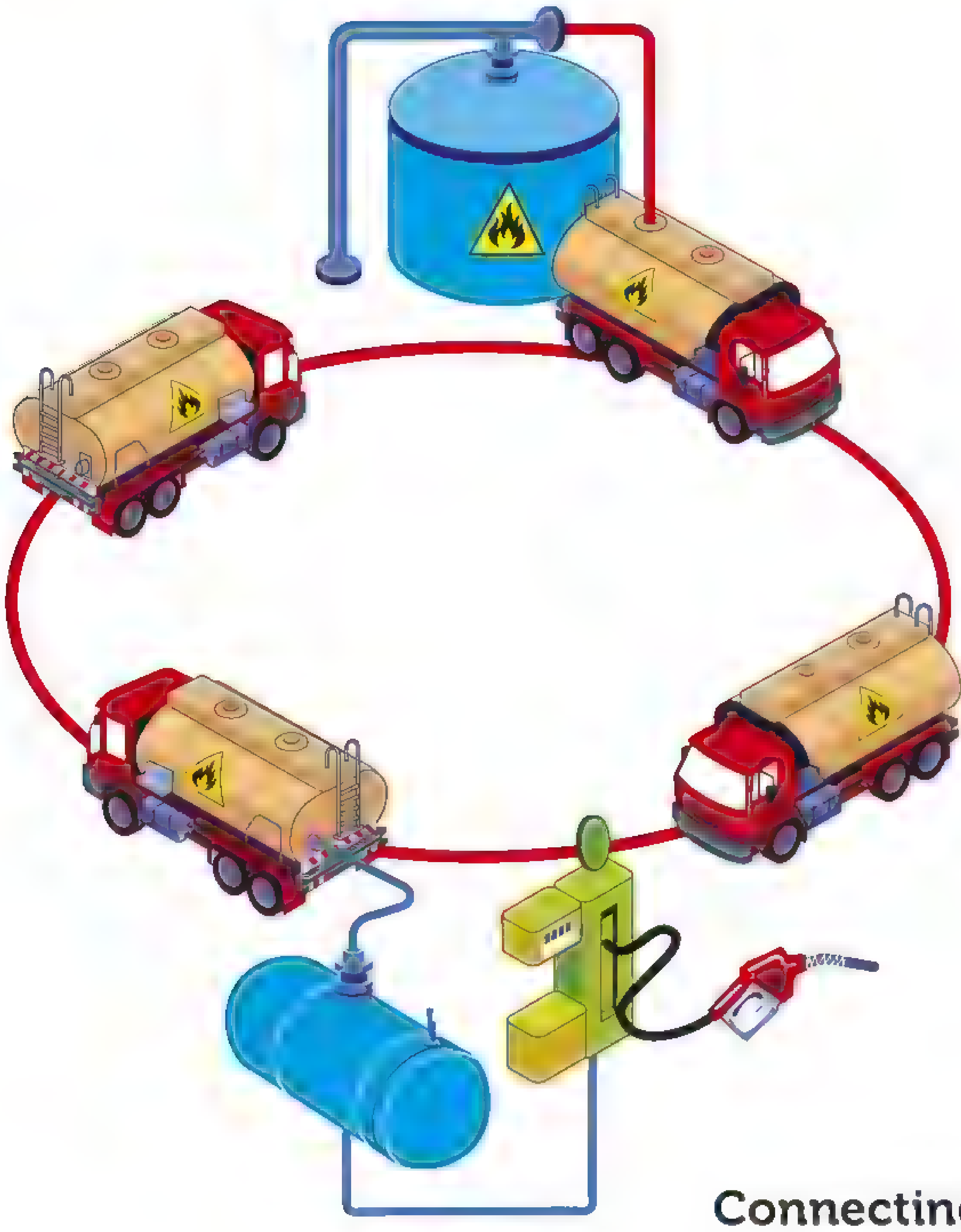
Voltage

A battery always states what **voltage** it supplies (figure 13). You can check the stated voltage with a **voltmeter.** You measure the voltage between the positive and negative terminals of the battery. The unit of voltage is the volt (V).

▶ figure 13
Various types of batteries: each voltage source has its own specific voltage.

The voltage and the current both refer to the way in which a flow of electricity transports energy. This flow is made up of small charged particles that move through a conducting material. The current tells you how many of those particles flow past every second. The voltage tells you how much electrical energy each particle is carrying.

The greater the current and voltage, the more energy is being transported per second. You can compare those aspects of a flow of electricity to petrol tankers (figure 14). The 'current strength' is the number of petrol tankers driving past per hour. The 'voltage' is the amount of petrol that each tanker holds. The greater the 'current' and 'voltage', the more petrol is being transported per hour.



◀ figure 14
You can compare the transport of electrical energy to the transport of petrol.

When you switch the current off the voltage has not disappeared. The particles are still there and they still have just as much energy. In the petrol tanker example, the tankers are still there and they still have petrol inside. They are just not moving any longer, which means that no energy is being supplied to the user. The energy transport only gets going again once a current starts to flow.

Connecting batteries together

You often need more than a single battery to obtain the right voltage. For the remote control in figure 15, for example, you need two 1.5 V dry batteries. You have to connect the batteries up in series. That means that you connect the positive terminal of one battery to the negative terminal of the other battery. They will then provide a combined voltage of 3.0 volts.

If you connect four 1.5 V batteries in series, i.e. always with the positive terminal of one battery connected to the negative terminal of the next, then together they will provide a voltage of 6.0 V. The general rule is that:

If you connect batteries in series, you can add their voltages together.

If you accidentally connect one of the four batteries the wrong way round, it will work against the other three. The total voltage will then be 1.5 + 1.5 + 1.5 − 1.5 = 3.0 V.

▶ figure 15
This remote control takes two 1.5 V batteries.

Nova © Uitgeverij Malmberg

Safe and unsafe voltages

The **mains voltage** in electrical sockets in the Netherlands is 230 V. Voltages this big are definitely quite hazardous. If you touch a conductor that is at 230 V, you will at the very least get an unpleasant shock. Under unfavourable circumstances, it can even be potentially fatal. Devices that operate on 230 V therefore need to be properly insulated so that you cannot touch components that are 'live' at a high voltage.

The voltage that a battery supplies is far less than 230 V. This kind of low voltage is not dangerous. In fact, if you touch the terminals of a battery, you do not feel anything. A value of 24 V is often used as a safe limit. Battery-operated devices are well below that. You therefore do not need to be afraid that a mobile phone or a cordless drill will give you a shock.

Many devices operate on a lower voltage than 230 V. If you still want to be able to plug them into a mains socket, you need a **transformer.** This is a device that converts the mains voltage down to a low voltage. The adapter that you use to recharge a mobile phone contains a transformer that converts the mains voltage of 230 V to a voltage of 5 V (figure 16).

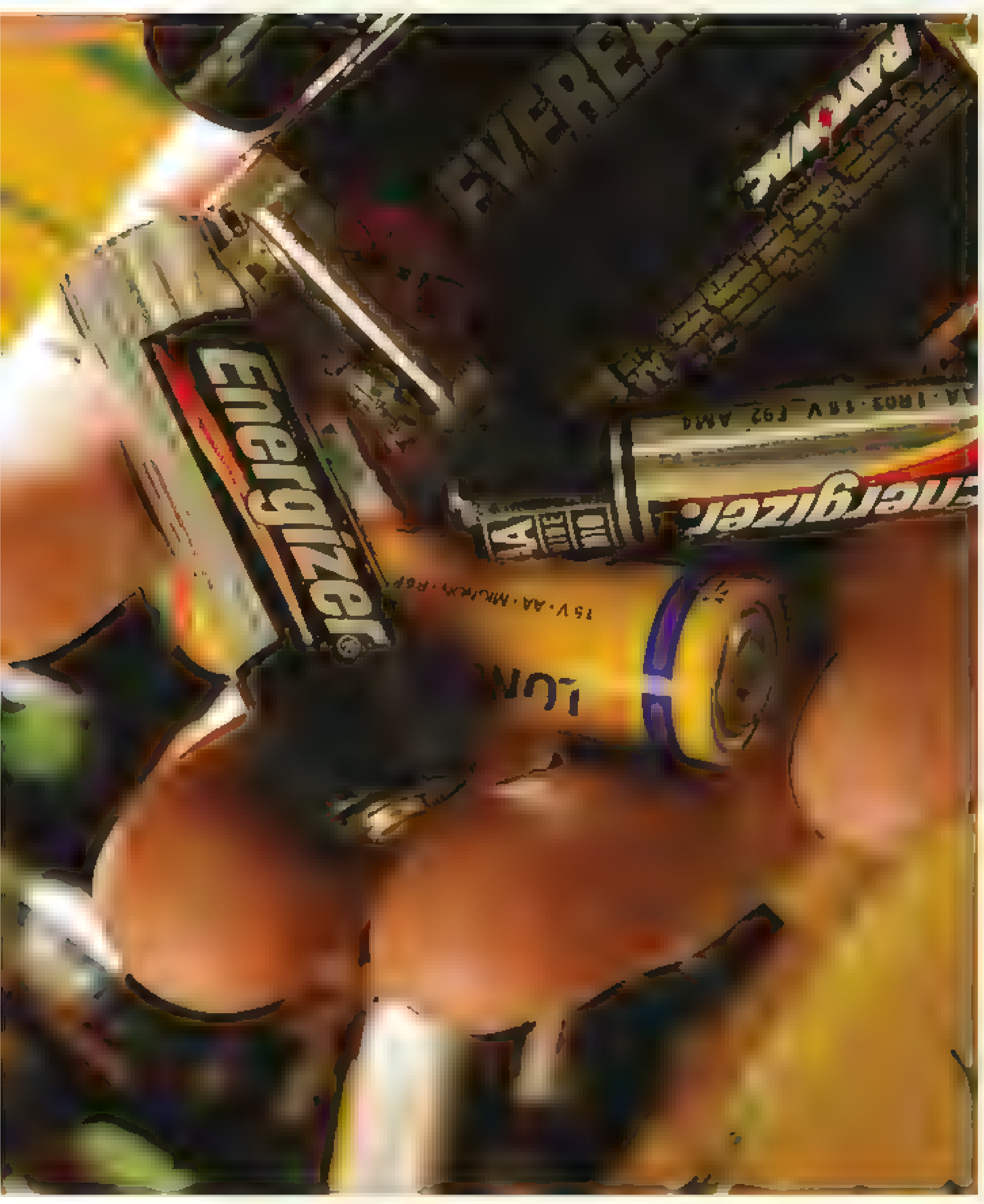
▲ figure 16
an adapter for a mobile phone

Plus Chemical voltage sources

We say that batteries are chemical voltage sources, because the voltage is generated using **chemical reactions.** In these reactions, the original substances are consumed and new substances are generated instead. When the original substances have been used up, the battery does not deliver a voltage any longer: it is 'flat'.

In rechargeable batteries, you can also make the reactions go in the opposite direction. That happens when you recharge the battery. The substances that were previously created in the battery then disappear. In their place, you get the original substances back. This does not happen in non-rechargeable batteries. These have to be thrown away when they are flat (figure 17).

Batteries often used to contain cadmium or mercury. These elements are highly toxic and may therefore no longer be used in batteries. Even so, batteries do still contain substances that are harmful to the environment. This is why batteries should be treated as small-scale chemical waste items. This applies to both rechargeable and non-rechargeable batteries. However, rechargeable batteries are less damaging to the environment because they last much longer.



▲ figure 17
Batteries are small-scale chemical waste.

Exercises

14 Answer the questions below.
- **a** Which three types of voltage sources are mentioned in this section?
- **b** How can you calculate the voltage of four batteries connected in series?
- **c** Why do devices that operate on 230 V need to be properly insulated?
- **d** What is the name for a device that converts mains voltage into a low voltage?

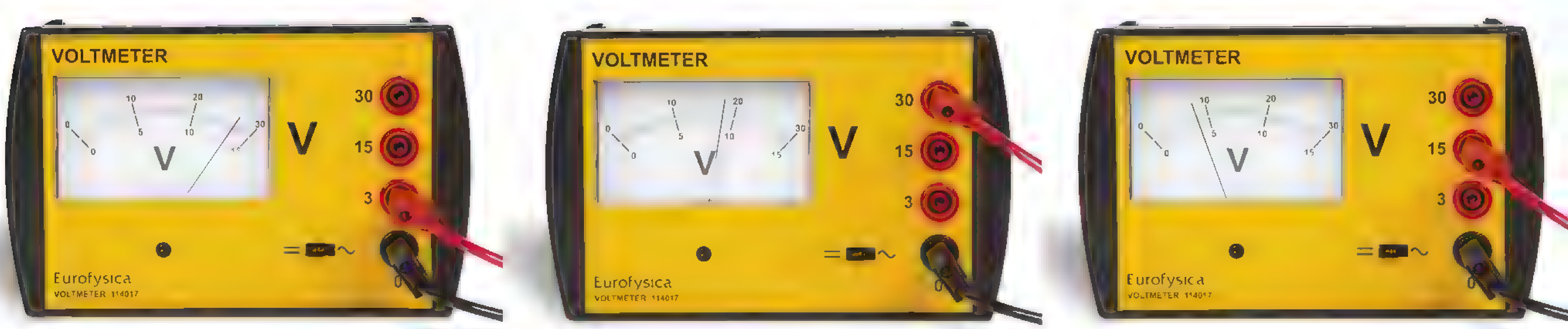
15 An electric current is made up of small particles that move through a conducting material.
- **a** What variable describes how many particles are flowing past per second?
- **b** What variable describes how much electrical energy each particle is carrying?

16 Copy and complete:
- **a** You can use a ...... to measure the voltage that a voltage source delivers.
- **b** The magnitude of the voltage is measured in ......, abbreviated to the letter ....
- **c** The ...... (the voltage of the electrical sockets) in the Netherlands is 230 V.
- **d** A useful rule of thumb is that voltages of up to ......V do not present a risk.

17 The voltage supplied is always stated on batteries.
Why do dynamos not state the voltage that they deliver?

18 Figure 18 shows you three photos of a voltmeter. Learning how to read a voltmeter is covered in 'Skills 7'.
Read off the voltages that the three meters are showing and write them down.

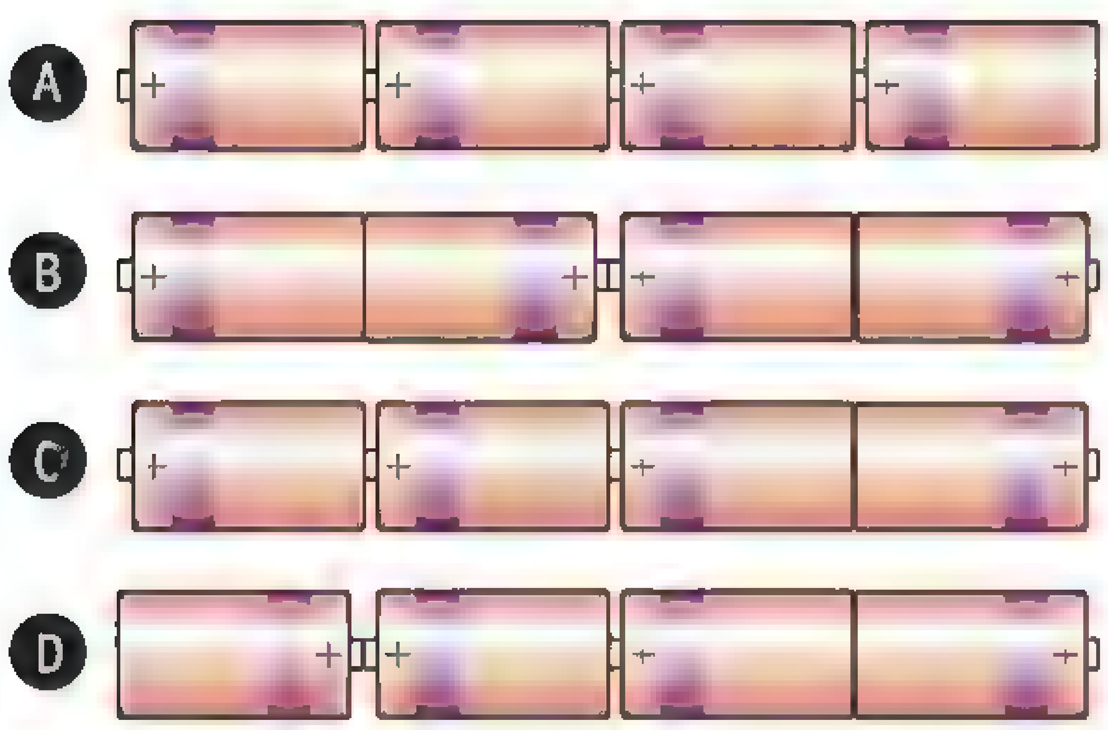
If you need more practice, go to the V-trainer.



▲ figure 18
What voltages are the three voltmeters reading?

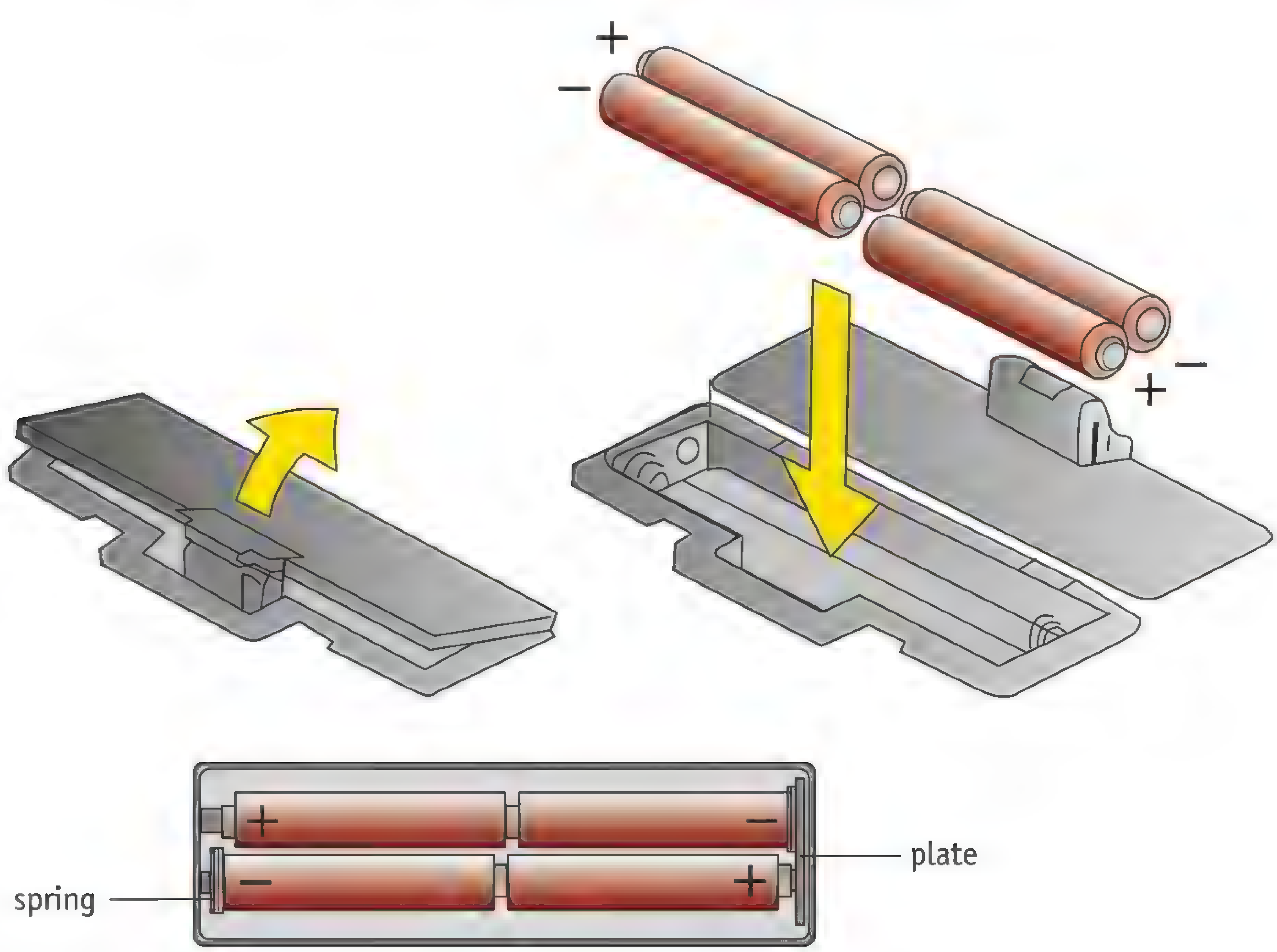
19 You need worksheet 5-1 for this exercise.
- **a** Make a drawing next to point a showing how you should connect the voltmeter to read 1.2 V.
- **b** Make a drawing next to point b showing how you should connect the voltmeter to read 2.4 V.
- **c** Make a drawing next to point c showing how you should connect the voltmeter to read 3.6 V.

20 In figure 19, 1.5 V batteries are combined in different ways.
What is the voltage delivered by the combination of batteries in:
- **a** figure 19a?
- **b** figure 19b?
- **c** figure 19c?
- **d** figure 19d?



▲ **figure 19**
four combinations of batteries

21 Figure 20 shows you a picture from the manual for a set of bathroom scales. The scales work on four AA batteries of 1.5 V.
- **a** Why is the plate on the right-hand side made of a conducting material?
- **b** Is the spring on the left also made of a conducting material? Explain.
- **c** How are the batteries connected, if you fit them in the compartment correctly?
- **d** What is the voltage that the four batteries provide together?

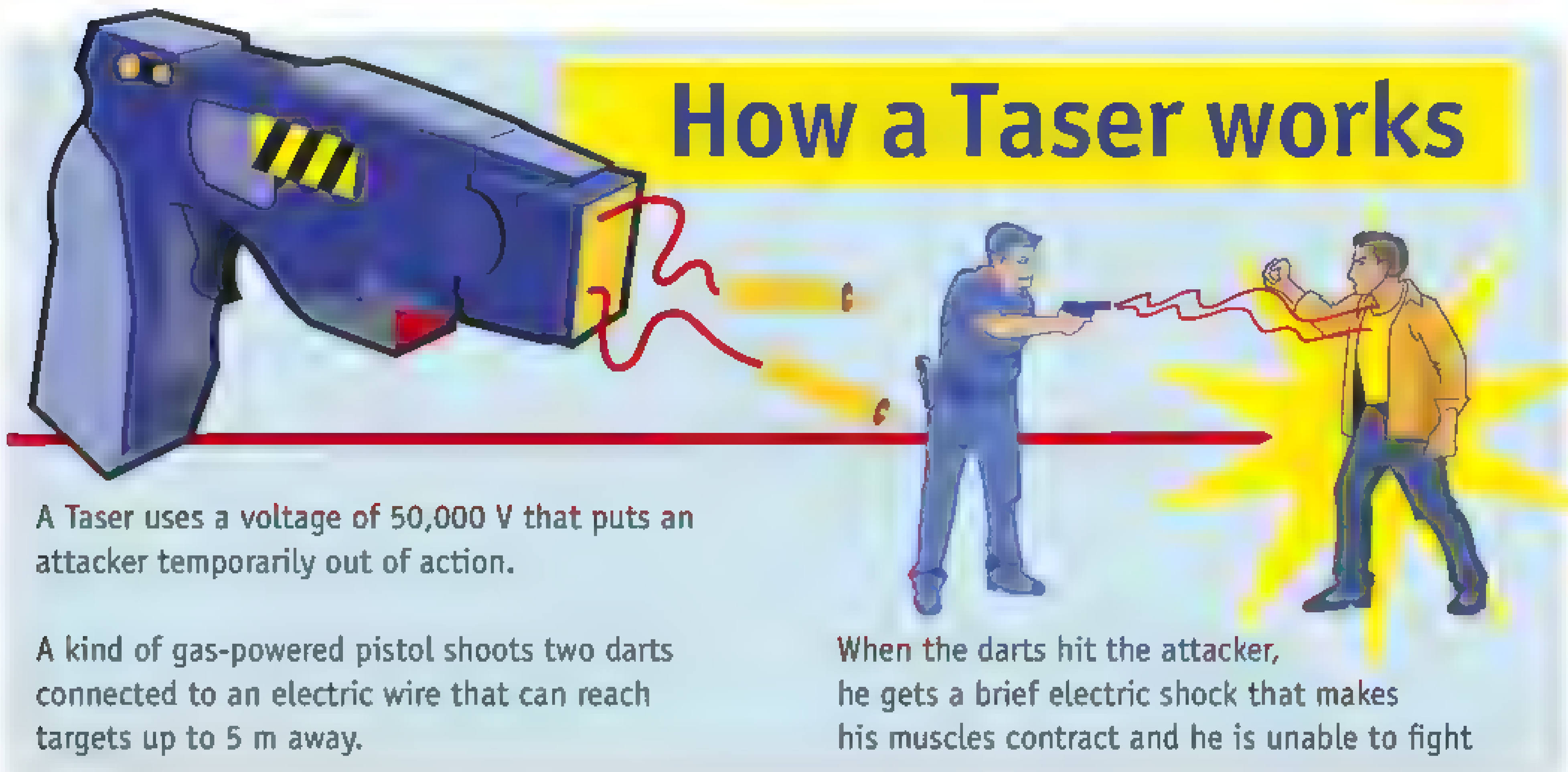


▶ **figure 20**
This is how the batteries have to be put in the scales.

*22 A Taser is an electric shock weapon that is used by police forces in many countries. When the weapon is fired, two darts each connected to a conducting wire are released (figure 21). If those barbed darts hit someone, the person receives a very short electric shock. The electric shock is very painful and puts the affected person temporarily out of action.

a Explain why a Taser shoots two darts, not one.

b The voltage across the darts is very high, at about 50,000 V. Even so, being hit by a Taser is almost never fatal.
Explain how this is possible.



▶ figure 21
How a Taser works.

*23 Search the Internet for information about electric cat fences.

a What is the maximum voltage that the energiser for an electric fence produces?

b Why does this type of generator produce short pulses rather than a constant voltage?

c What does a cat feel when it touches the electric wires?

d Make a clear drawing of the electric circuit that is created at that moment.

Plus Chemical voltage sources

24 People sometimes say, "This battery is flat." This obviously doesn't mean the battery is flat like a piece of paper.
So what do we mean when we say that a battery is 'flat'?

25 Rechargeable batteries are more expensive than non-rechargeable batteries. Explain:

a why rechargeable batteries can nevertheless work out as cheaper overall.

b why rechargeable batteries are also less damaging to the environment.

c why it was appropriate for b to say 'less damaging' than 'better'.

26 Search the Internet for information about car batteries.

a What is the voltage supplied by a car battery?

b How is a car battery recharged?

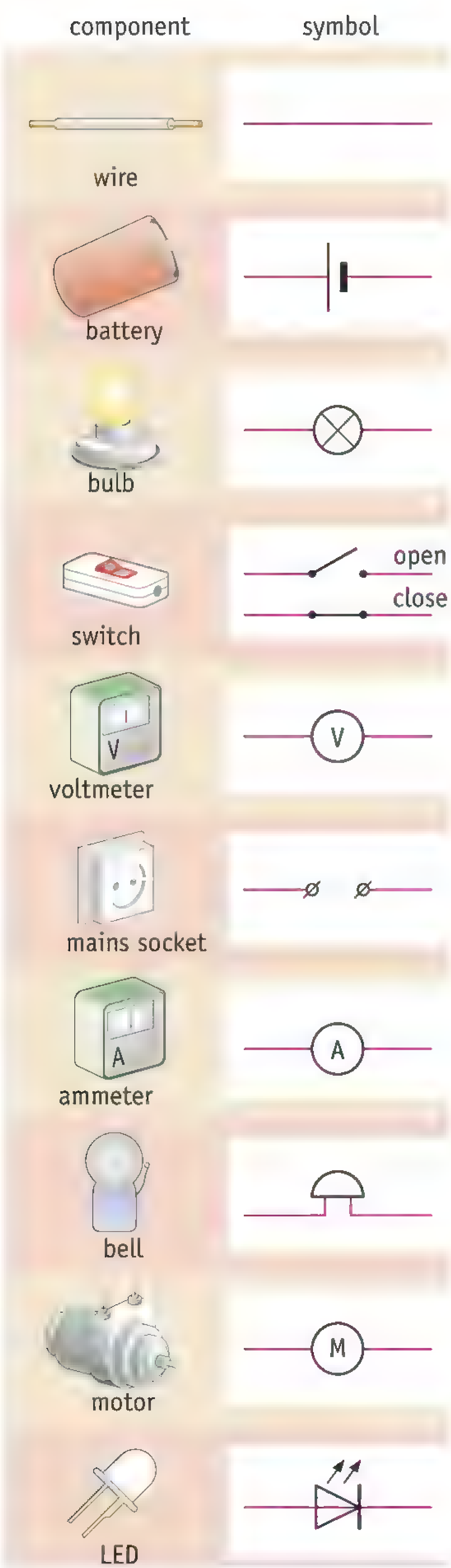
c What harmful substances are there in a car battery?

d What are the risks, for the environment and for you yourself?

e How should you dispose of a car battery that is old and no longer works?

Nova © Uitgeverij Malmberg

3 Circuits



▲ figure 22
symbols for circuit diagrams

You can connect bulbs, switches, wires and voltage sources together in various ways. Or to put it differently, you can make various different circuits with them. A circuit will always contain one or more closed loops through which electricity can flow.

Drawing circuits — Experiments 3 and 4

If you want to explain to someone what a particular circuit looks like, the best way is to use a drawing. Special symbols have been thought up to let you make clear circuit drawings. This type of drawing is called a **circuit diagram** (see figure 22).

Circuit diagrams are indispensable for experiments with electricity. The diagram shows you what components you need and how to connect them together. The book shows circuit diagrams for a lot of the experiments. Sometimes you have to draw a circuit diagram yourself. After you have collected together all the components, you build the circuit using the diagram.

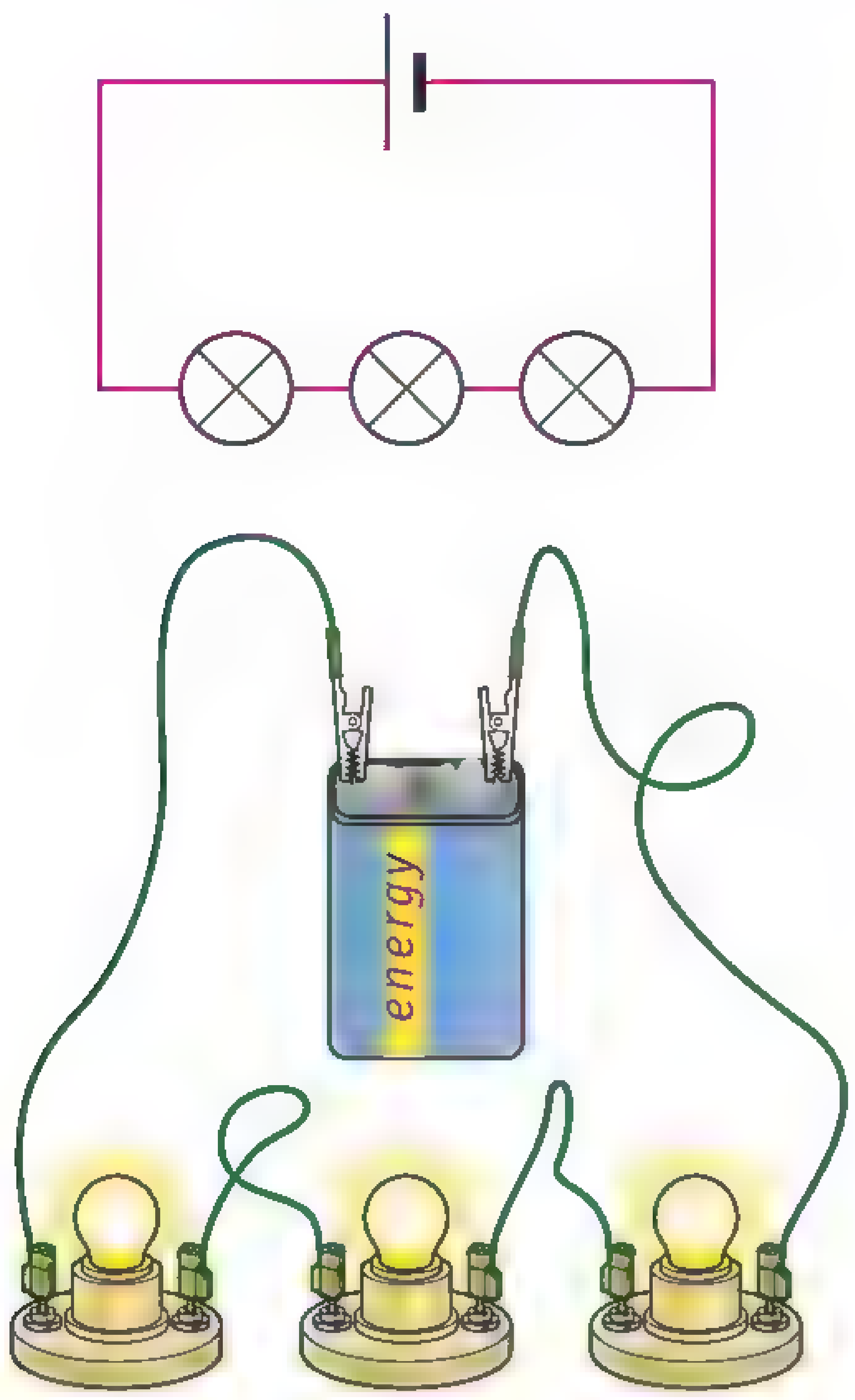
Circuit diagrams are also used when developing electrical and electronic devices. First, the design team makes a circuit diagram on which all the components and their connections are represented schematically. Once that diagram has been approved, the team works out the best (and cheapest) way of putting the circuit together.

Series circuits — Experiments 5 and 6

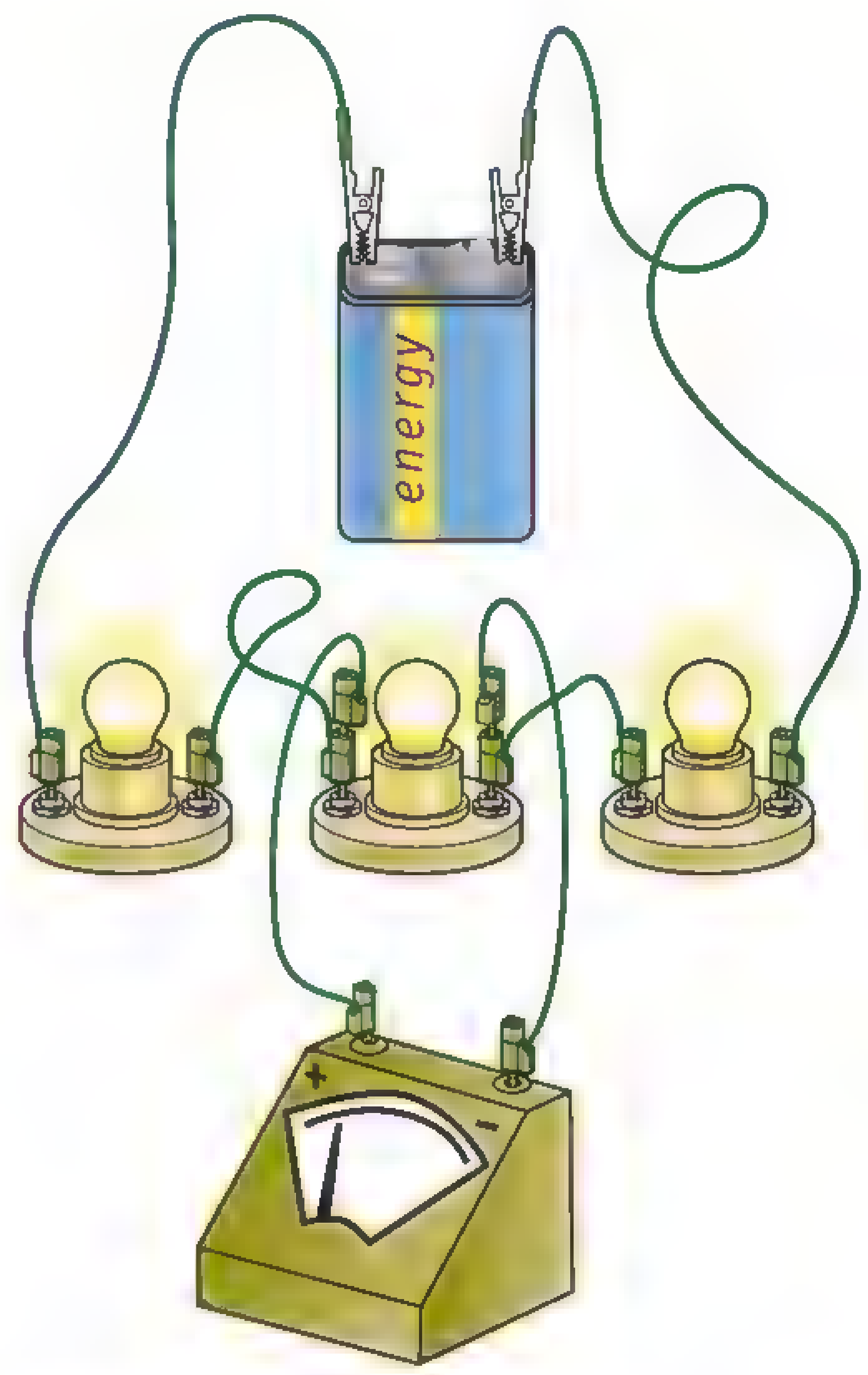
Figure 23 shows you a **series circuit** with three bulbs. A series circuit has no branches: there is just one current loop. If any one of the bulbs blows, the circuit is broken and so all the bulbs go out. Connecting bulbs in series is therefore not very practical. You want the other bulbs to keep working if one bulb blows.

However, you do want a switch to be connected up in series with the device that is to be switched on and off. When you turn the switch OFF, you are opening the circuit and so the device is turned off. When you turn the switch ON, you are closing the circuit and so the device is turned back on.

The current in a series circuit is the same throughout. It does not matter where you measure the current in figure 23: between the battery and the first bulb, between the first bulb and the second bulb, between the second bulb and the third bulb, or between the third bulb and the battery. You will always measure the same value.

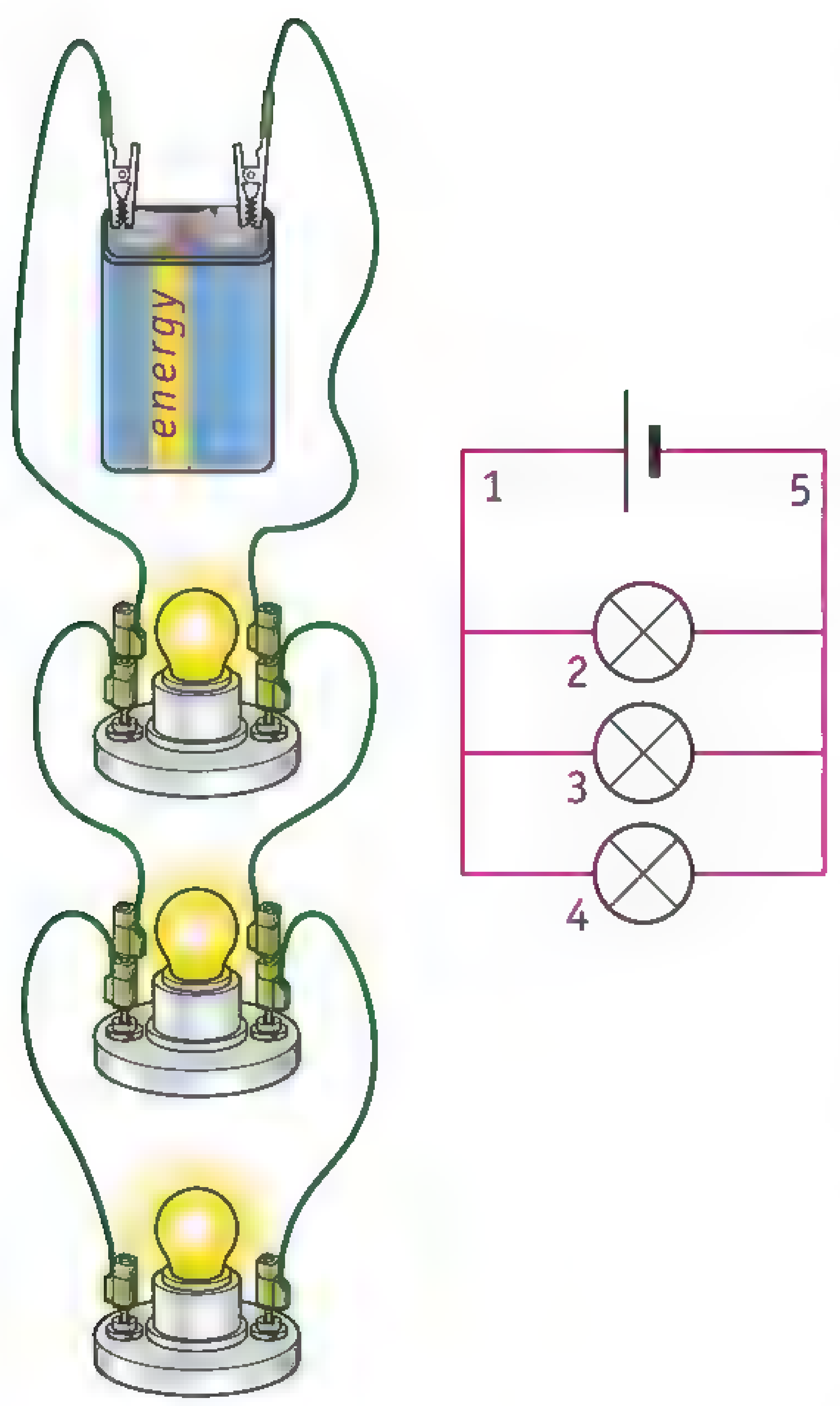


▲ figure 23
a series circuit with three bulbs



▲ figure 24
Measuring the voltage across a single bulb.

The electrical energy that the particles are transporting will be distributed between the three bulbs. If you have used three identical bulbs, each of them will receive one third of the **source voltage** (the voltage supplied by the battery). You can check that by measuring the voltage across a single bulb, as drawn out for you in figure 24.



▲ figure 25
a parallel circuit with three bulbs

Parallel circuits   Experiment 7

When two or more electrical devices are connected in a circuit they are almost always joined in parallel. This has three benefits:

1 Each device can then be switched on and off with its own switch.
2 If one device breaks, the others can continue to operate.
3 Each device receives the full voltage of the voltage source.

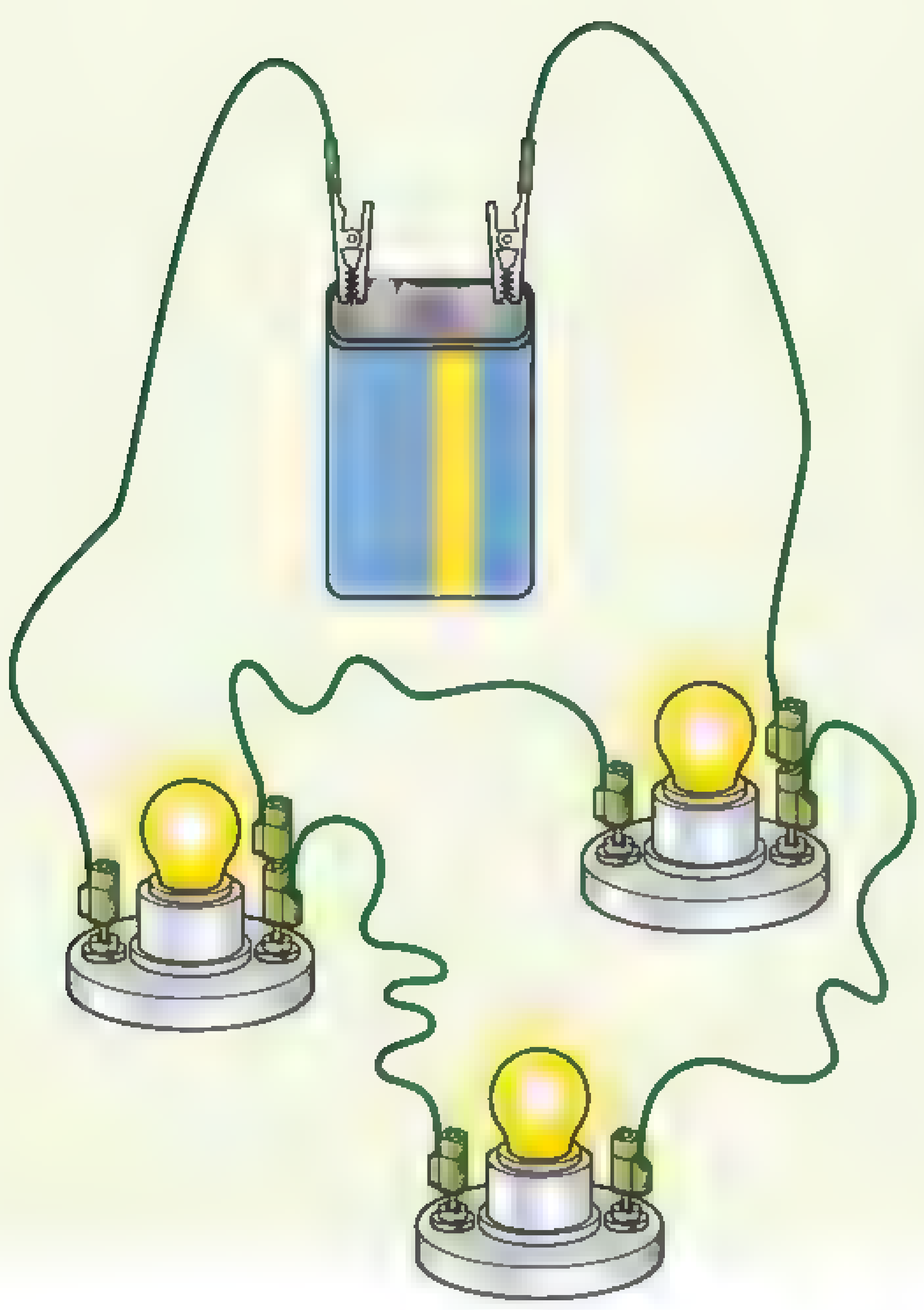
Figure 25 shows you a **parallel circuit** with three bulbs. Each bulb is directly connected to the source voltage of 4.5 V. The circuit is branched so that each bulb is supplied with electrical energy separately. The parallel circuit therefore comprises three circuit loops, each of which can be opened and closed independently.

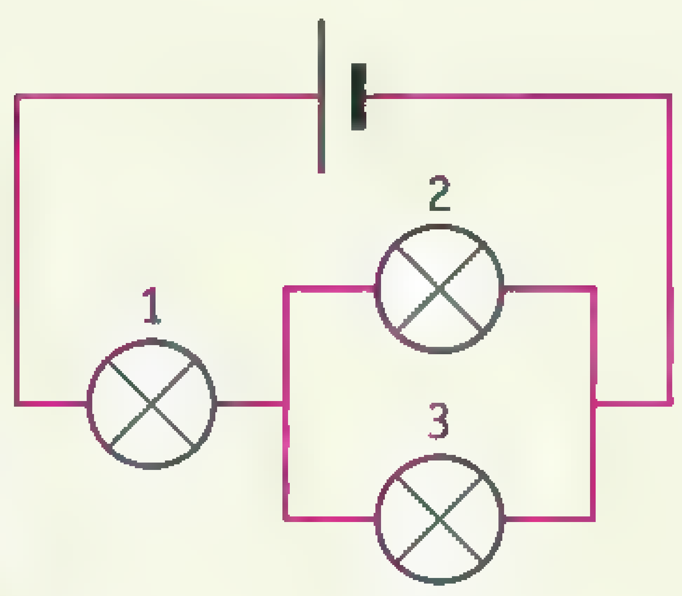
The current splits at the point in a parallel circuit where the circuit branches. The current in figure 25 is split into three. The current in the unbranched parts (at 1 and 5) is called the **total current.** The current in each of the branches (at 2, 3 and 4) is 1/3 of the total current. Therefore the current in a parallel circuit does not have the same value everywhere, unlike the situation in a series circuit.

Plus Mixed circuits Experiment 8

In a **mixed circuit**, some components are connected in series and others in parallel. Figure 26 shows an example of this kind of circuit: bulbs 2 and 3 are connected in parallel with one another, but are in series with bulb 1.

A mixed circuit will behave differently to either a series circuit or a parallel circuit. If you unscrew bulb 1, bulbs 2 and 3 will also go out. There is no longer a closed circuit then. But if you unscrew bulb 2, bulbs 1 and 3 will stay lit. This is because there is then still a closed circuit through them.





You can often work out what the current is at various places in a mixed circuit. Bulb 1 will for example be brighter than bulbs 2 and 3. Think about it: all the current that goes through bulb 2 plus all the current that goes through bulb 3 has to go through bulb 1 too. There is as much current going through bulb 1 as there is going through bulbs 2 and 3 together.

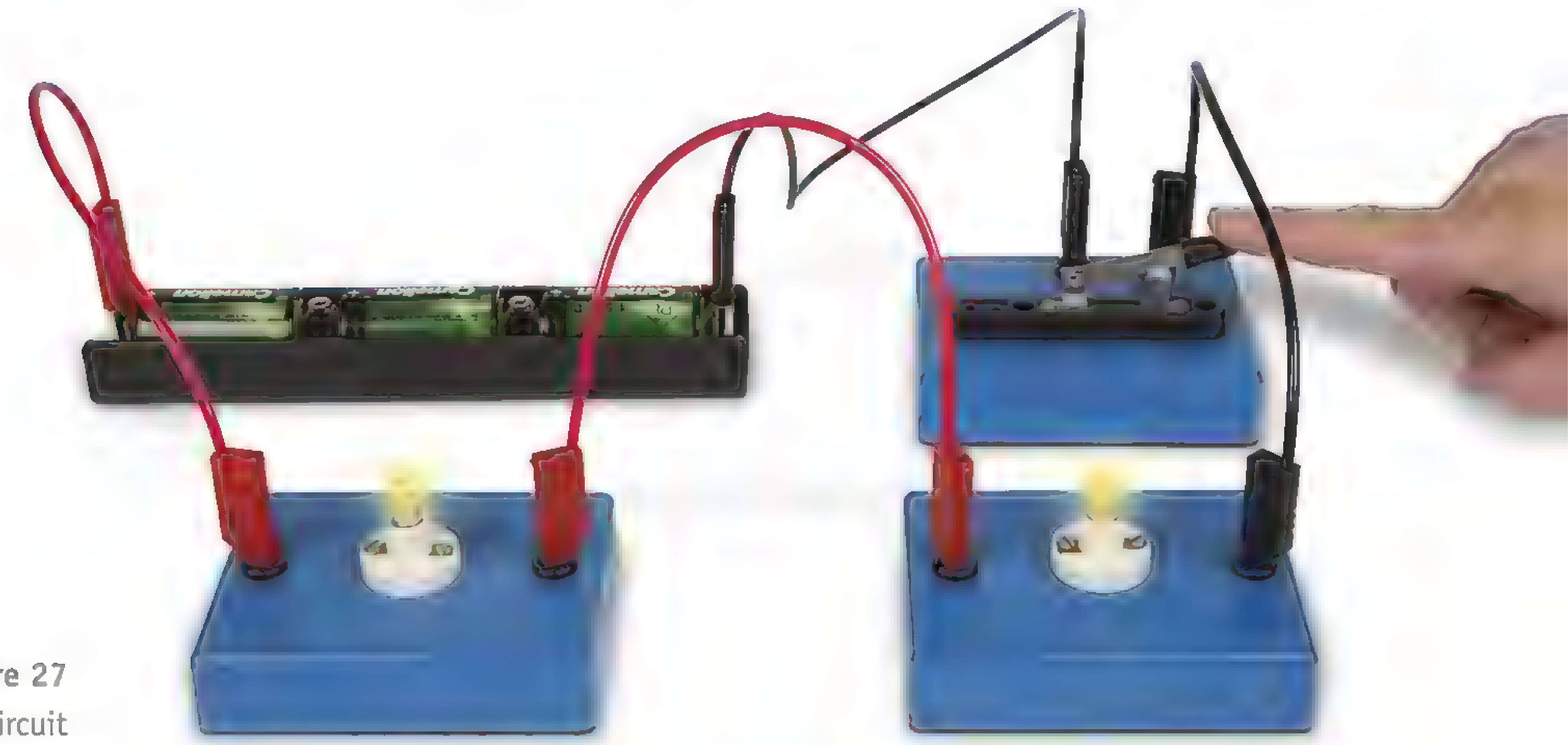
▲ figure 26
a mixed circuit with three bulbs

Exercises

27 Answer the questions below.
- **a** How do you need to connect bulbs if you want to switch them on and off independently?
- **b** In what sort of circuit does the current have the same value at all points?
- **c** Why are electrical devices almost always connected in parallel?
- **d** What does the total current in a parallel circuit mean?

28 Draw the circuit diagram symbols for:
- **a** a bulb.
- **b** a switch.
- **c** a bell.
- **d** a voltmeter.

29 Figure 27 shows you a photo of a circuit.
Draw the circuit diagram for this circuit.



▶ **figure 27**
a circuit

30 Barry connects up three identical bulbs in series. He then connects the bulbs up to a 9 V battery.

- **a** Work out what the voltage is across each of the bulbs.
- **b** Barry sees that the bulbs are not very bright. His teacher tells him that the bulbs will be brighter if Barry increases the source voltage to 18 V. “Use a second battery,” he says, “and it should work OK then.” Explain how Barry must connect the two batteries.
- **c** What voltage is being applied to each bulb if the source voltage is 18 V?

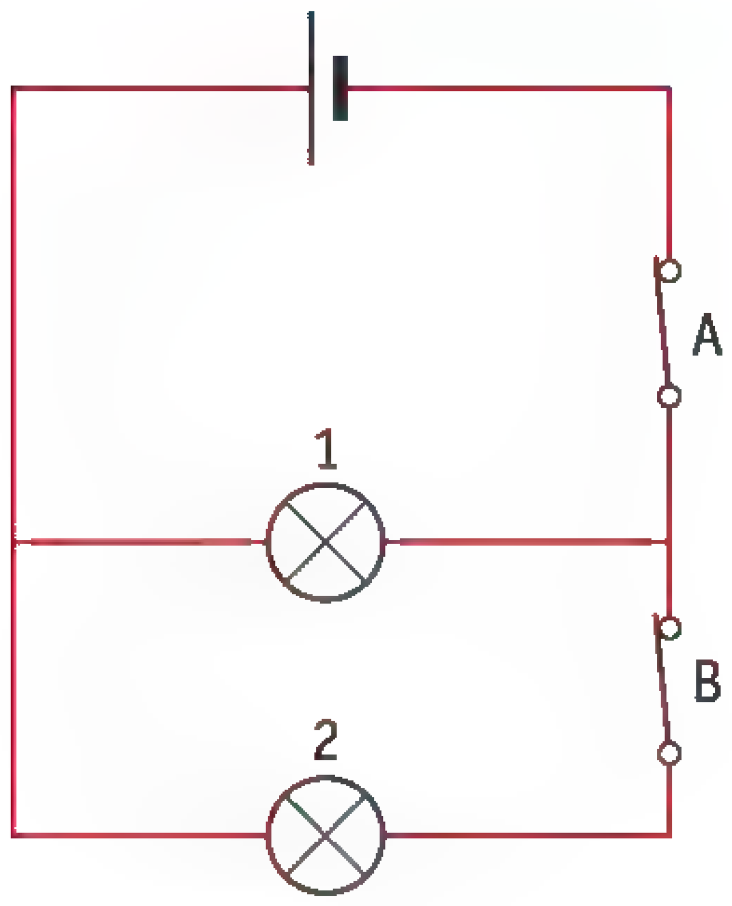
31 A living room is lit by two floor lamps and one desk lamp. The bulb in one of the floor lamps blows.

- **a** Does anything then happen to the other floor lamp?
- **b** Does anything happen to the desk lamp?
- **c** So how are the wall sockets in a house connected?

32 A car has indicator lights, brake lights, headlights, reversing lights and so forth.
How are these lights connected: in series or in parallel? Explain your answer.

33 Amanda has made a circuit in which two bulbs are connected up in parallel to a battery.

- **a** Draw the circuit diagram for this arrangement. Label the bulbs 1 and 2.
- **b** Amanda wants to add a switch that will let her turn bulb 2 on and off while bulb 1 remains lit.
  Draw this switch in at the correct place on the circuit diagram.



▲ figure 28
a circuit

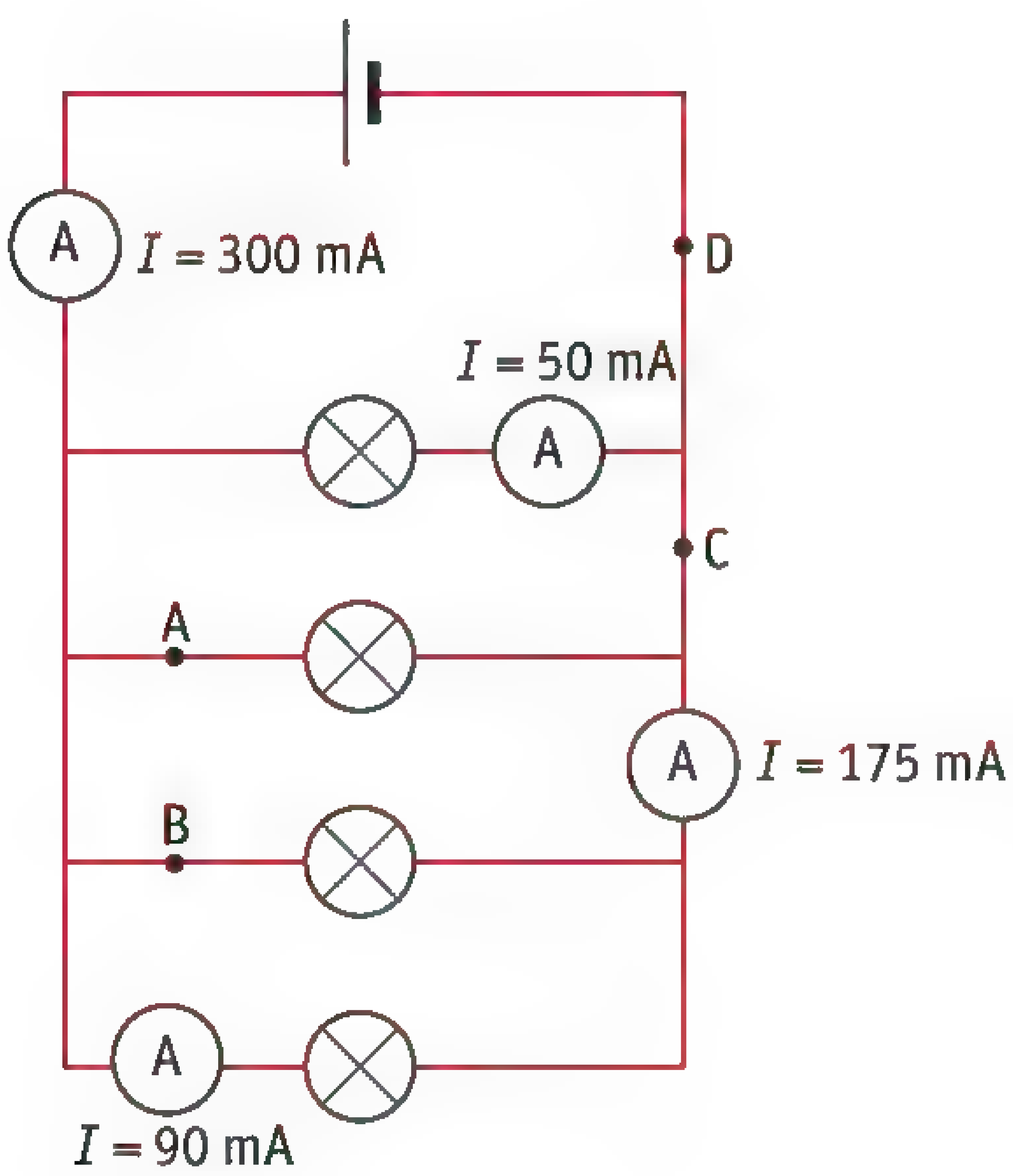
34 Study the circuit in figure 28.
Write down which bulbs are lit:
a if switch A is open and switch B is closed.
b if switch B is open and switch A is closed.
c if both switches are closed.

***35** Andrew has built the circuit shown in figure 29. He has measured the current at four points.
Calculate what the current is:
a at point A.
b at point B.
c at point C.
d at point D.

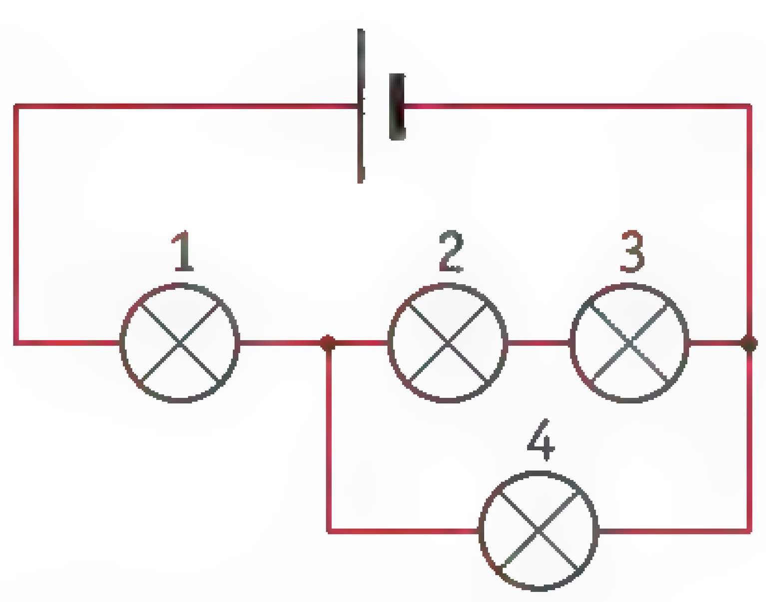
Plus Mixed circuits

36 Study the circuit in figure 30. All the bulbs are identical.
a Which bulbs go out if you unscrew bulb 1?
b Which bulbs go out if you unscrew bulb 2?
c Which bulbs go out if you unscrew bulb 3?
d Which bulbs go out if you unscrew bulb 4?
e Why does bulb 1 shine the most brightly?

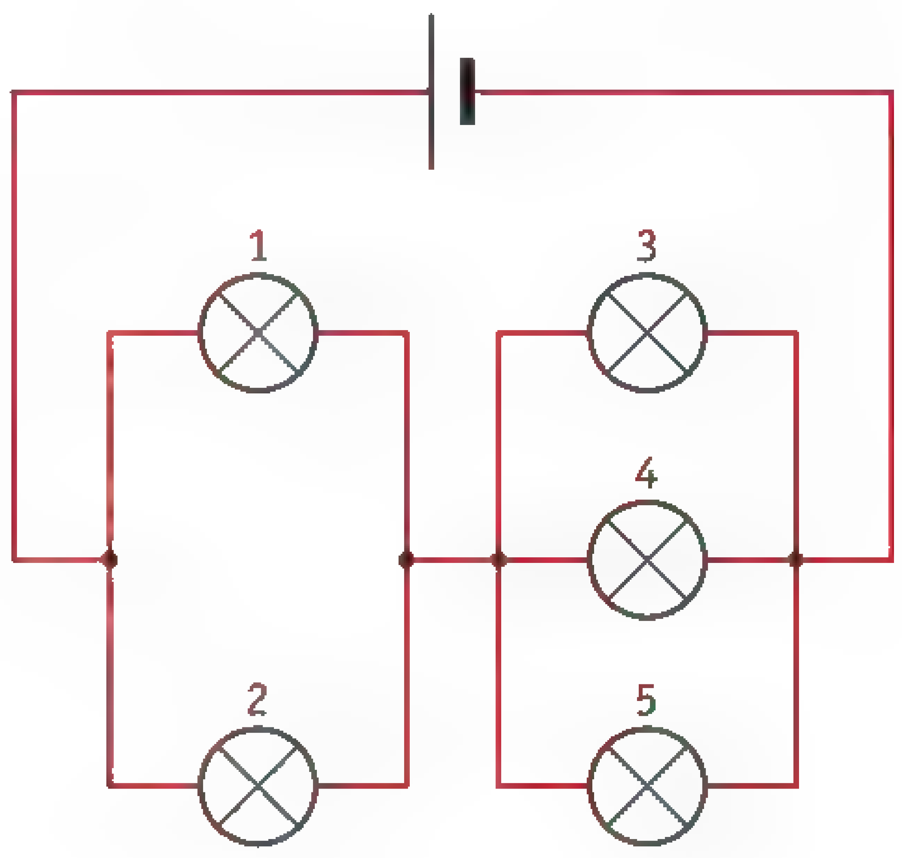
37 Study the circuit in figure 31. All the bulbs are identical.
a Which bulbs are connected in parallel?
b Why do bulbs 1 and 2 shine more brightly than bulbs 3, 4 and 5?
c Why do all the bulbs shine equally brightly if you unscrew bulb 3?
d You know that the battery provides a current of 0.3 A.
What is the current flowing through each of the five individual bulbs?



▲ figure 29
Andrew's circuit



▲ figure 30
a circuit with four bulbs



▲ figure 31
a circuit with five identical bulbs

4 Power and energy

▲ figure 32
The packaging of a bulb always states the power.

A mobile phone would be much less useful if you had to keep connecting it up to the charger. It is therefore important that a mobile uses the available electrical energy as efficiently as possible. The more economically the device can use it, the longer it will be before the battery has to be recharged.

The power of a device

A laptop uses more electrical energy over the same period of time than a tablet does. You say that a laptop uses more power than the tablet does. The **power** indicates how much electrical energy a device uses per second. The greater the power rating, the more electrical energy the device 'gobbles up' in a single second.

The power consumption of many devices is listed on the packaging. That is the case for the bulb in figure 32, for instance. The power is generally given in watts (W), or sometimes in milliwatts (mW) or kilowatts (kW). If the power consumption is not constant, the maximum value is stated.

The power consumption of some devices varies a great deal. For example the power used by a mobile increases a lot when you are phoning or using the Internet. If the phone is on standby, very little power is used. There are also devices that do use a constant power, such as a pocket torch or an electric clock.

Calculating the power

The power of a device depends on two factors: (1) the operating voltage of the device, and (2) the current flowing through the device. That is logical if you think about what the variables 'voltage' and 'current' mean. The voltage tells you how much energy a single particle supplies to the device, and the current tells you how many particles are delivering their energy every second. Together, they determine the power.

The 'tanker model' from Section 2 will help you understand this. You can compare the power to the quantity of petrol that is transported per hour along a particular road. You can then see for yourself that the quantity depends on two factors: (1) how much petrol each tanker is carrying – the 'voltage' – and (2) how many tankers are going past every hour – the 'current'.

You can therefore calculate the power using the following formula:

power = voltage x current

or in symbols:

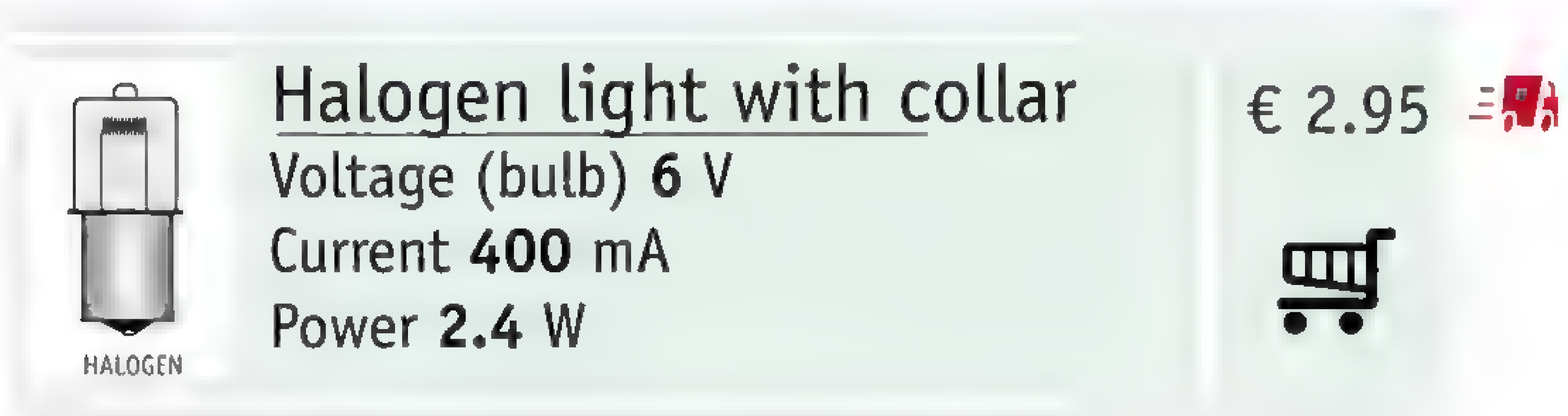
$P = U \cdot I$

If you use a voltage U in volts and a current I in amps, this gives you the power P in watts (W).

Worked example 1
You can buy spare bulbs for torches on a website (figure 33).
Check whether the power of the bulb in figure 33 has been calculated correctly:

data	$U = 6$ V
	$I = 400$ mA $= 0.4$ A
required	$P = ?$
working out	$P = U \cdot I$
	$= 6 \times 0.4$
	$= 2.4$ W

This is the same as the value that is given on the website.



▶ figure 33
an offer on a website

Power, time and energy consumption

A device such as a mobile phone or a tablet can only run for a limited time on its battery. The greater the power of the device, the more quickly the battery will run out. All sorts of ways have therefore been thought up to help keep the power consumption of a device low.

The power of a device is the sum of the power consumed by all the individual components. The device's designers therefore choose components that use energy economically. If two screens offer roughly the same performance, the screen with the lower power rating will be preferred.

The software also helps keep the power down. If you do not use a mobile or a tablet for a little while, the software switches off as many components as possible. For instance the screen will go black after just a few seconds (figure 34). This immediately reduces the overall power consumption of the device.

However there is a limit to how far the power can be reduced and so a great deal of research is also done into increasing the storage capacity of batteries. If a battery can store more electrical energy, a device can run on that battery for longer (at the same power).

▶ figure 34
A mobile screen goes blank.

Plus The capacity of a rechargeable battery

It takes much longer for some rechargeable batteries to run out than others. You can work this out from the **capacity** that is stated on the battery (figure 35). The units that the capacity of a battery are usually given in is milliamp-hours (mAh).

You can calculate the capacity by multiplying the current by the number of hours that the battery can supply that current for. The formula for the capacity is therefore:

$$C = I \cdot t$$

If you give the current I in mA and the time t in hours (h), then you get the capacity C in mAh.

If a battery has a capacity of 2000 mAh, then it can deliver a current of 10 mA for 200 hours. But if the same battery has to supply a current of 500 mA, it will be flat after just 4 hours.

▲ figure 35
The capacities of these three batteries are clearly stated on them.

Exercises

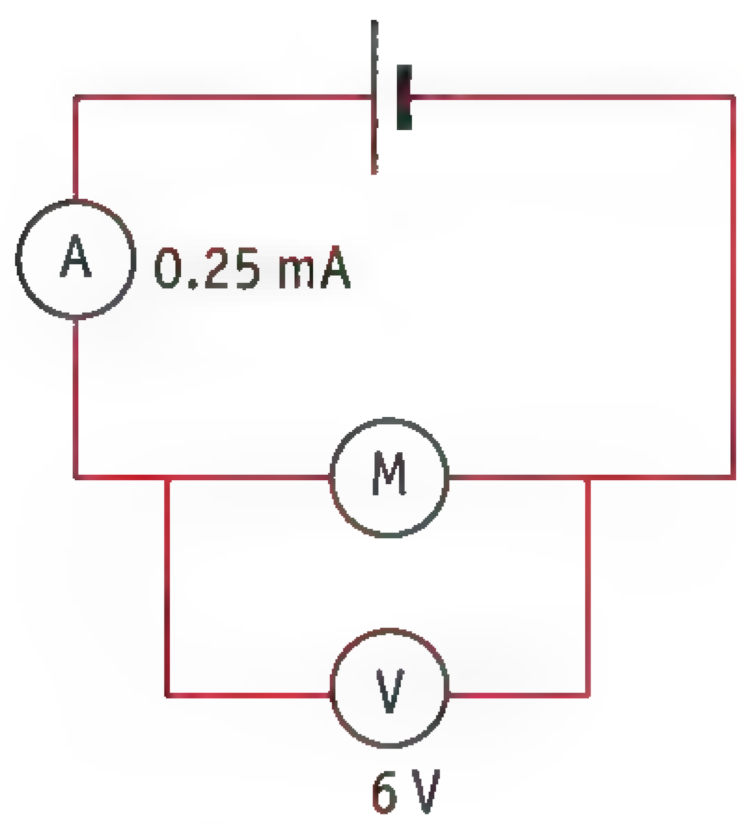
38 Answer the questions below.
- **a** What factors does the power of an electrical device depend on?
- **b** What formula can you use for calculating the power of a device?
- **c** Why is the power of a mobile kept as low as possible?
- **d** How does the software in the phone help keep the power consumption low?

39 Copy table 1 and fill in the missing data.

▼ **table 1** electrical variables and units

variable	symbol	unit	symbol
voltage			V
		ampere	
	P		

40 Five devices that run on electrical energy are listed below.
drill (cordless) – electric toothbrush – wristwatch – calculator – TV (wide screen)
List these devices in order of their power consumption: the device that uses least first, and the one that uses most last.



▲ **figure 36**
Miranda's experiment

41 Miranda is doing the experiment that has been drawn in figure 36.
- **a** Note the voltage and the current strength.
- **b** Calculate the power of the motor.

42 See 'Skills 12' at the back of the book.
Data for three bulbs is given in figure 37. One data item has been left out for each of the bulbs.
- **a** Calculate the power consumed by bulb a.
- **b** Calculate the voltage that bulb b is running at.
- **c** Calculate the current that is flowing through bulb c.

43 The screen of Frank's computer runs on a voltage of 12 V. When the screen is on, the current is 2.0 A.
- **a** Calculate the power used by the screen.
- **b** When the screen is in standby mode, the power is 0.6 W. Calculate the current in standby mode.

bulb a
voltage: 2.4 V
current: 500 mA

bulb b
current: 700 mA
power: 6.3 W

bulb c
voltage: 2.4 V
power: 48 W

▲ **figure 37**
three bulbs

44 There are no good electricity supplies at many places in developing countries. That is why the Firefly Solar LED Light was developed (figure 38). This is a lamp containing twelve LEDs. The lamp uses a rechargeable battery of 1.2 V. The battery is recharged using a solar panel that is supplied with it. The current flowing through one LED when it is lit is 18 mA. The LEDs are connected up in parallel.

a What is the total current strength when all twelve LEDs are on?
b Calculate the total power of the lamp when all twelve LEDs are on.
c Explain why the lamp is connected to a rechargeable battery rather than being connected directly to the solar panel.

▶ **figure 38**
The Firefly Solar LED Light, a lamp that is recharged from a solar panel.

45 Tina has a smartphone that she uses a lot.
How does the power used by her smartphone change:
a when she is called by a friend?
b if she turns the GPS off because she already knows where she is?
c if she sets the screen to be brighter?
d if she closes an app immediately after using it?
e when she plays an online game during the break?

46 There are various apps for smartphones that help make sure that the battery does not have to be recharged so often. This is done above all by turning off other programs and apps that you are not using but that keep connecting to the Internet.
a Explain why the battery then needs recharging less often.
b Explain what happens to the smartphone's power consumption.

▲ figure 39
a rechargeable battery

*47 An electric bicycle consumes about 175 W if you do not pedal at all to help it. You can also cycle yourself, using the electric motor only to make the pedalling easier. The motor then uses about 70 W.

a Explain why the power used by the electric motor is less when you are pedalling as well.

b If you do not pedal as well, the bicycle's range on a fully charged battery is 50 km.
How far could you go on a full battery if you do pedal as well?

c Does the distance you could travel on a full battery vary depending on whether you are going with the wind or against it? Explain your answer.

Plus The capacity of a rechargeable battery

48 A battery has a capacity of 2900 mAh. The voltage of the battery is 3.7 V. John is using this battery in his MP3 player. The MP3 player takes a current of 0.1 A.

a Calculate how many hours it will be before John has to recharge the battery.

b Calculate the power consumption of his MP3 player.

49 The rechargeable battery in figure 39 produces a voltage of 1.2 V. The battery is used in a pocket flashlight that has a power of 2.4 W.

a Calculate the current that flows through the pocket torch.

b Read the capacity of the battery from the figure and calculate how long it will be before the battery has to be recharged again.

50 Michael wants to know the right batteries to use for his camera. He finds information about it on the website. See figure 40. Michael's camera only works if the voltage is greater than 1 V.

a Which would be the best battery for Michael to use in his camera?

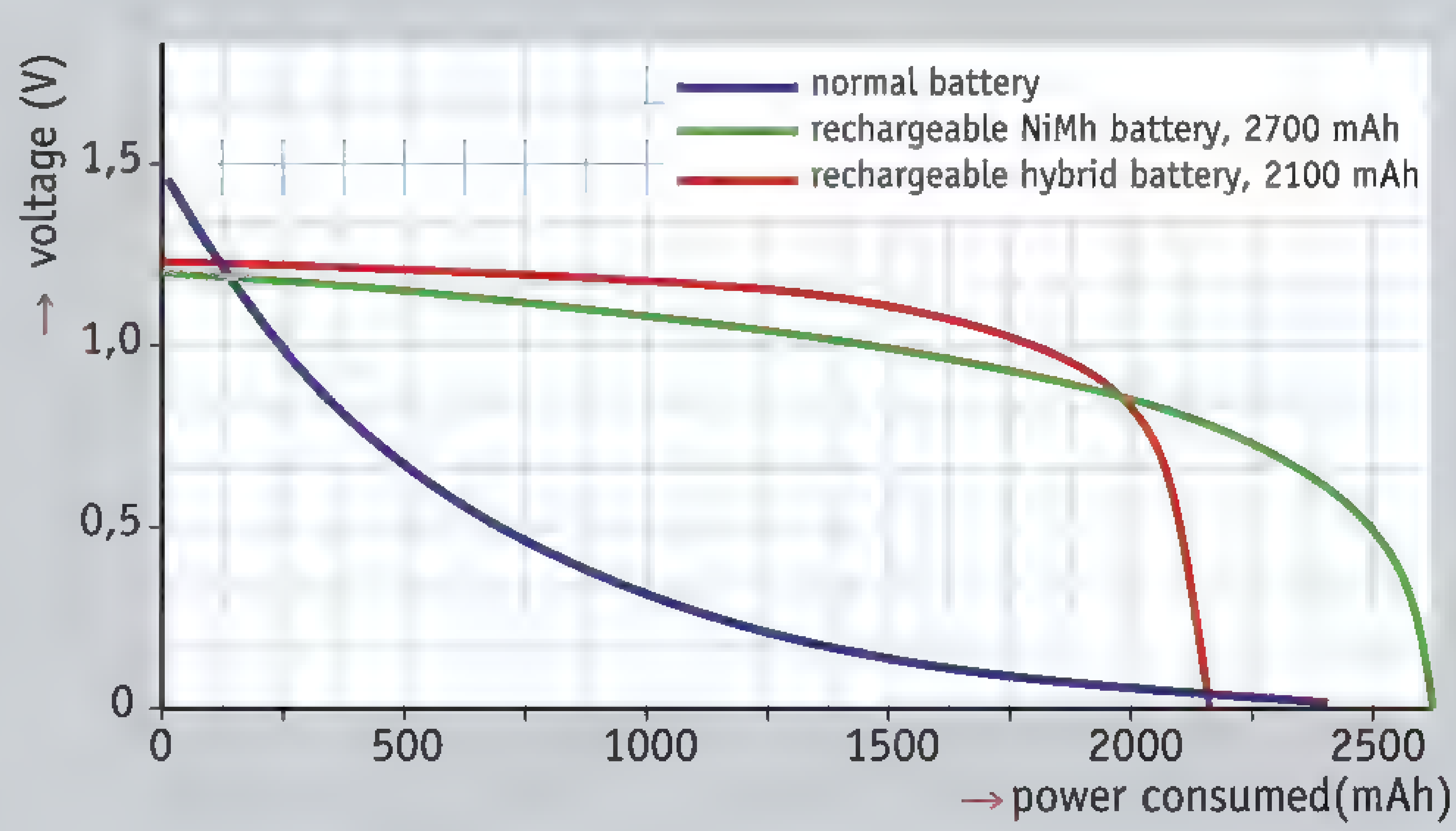
b Michael's MP3 player works on a voltage of just 0.5 V.
Which would be the most suitable battery for his MP3 player?

▼ figure 40
How the voltage varies for three different batteries.

So, is more mAh always better?

No, not always. As well as the voltage and the current, a battery has another variable that it is very important to understand properly. The awkward thing about this variable is that it is so unfamiliar that most batteries do not even mention it on the packaging. This can make choosing a battery very tricky.

The number of mAh stored in a battery does not say anything about how the voltage drops as the battery gets used up. The voltage of some batteries may drop quickly below the level that your device needs, although the battery itself is not yet exhausted.



Nova © Uitgeverij Malmberg

Experiments

Experiment 1 Conductors and insulators 15 min

Introduction
You can classify substances into conductors and insulators. Electric current can flow through conductors, but very little or no current can flow through insulators.

Aim
In this experiment, you will be investigating a number of substances to see whether they are conductors or insulators.

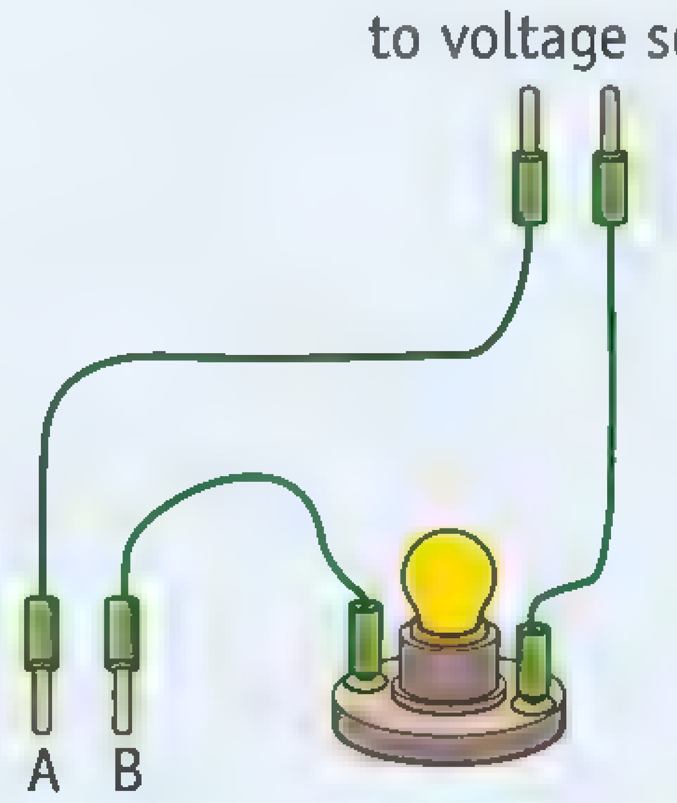
Requirements
- voltage source
- bulb in holder
- three wires
- copper rod
- seven other objects

Doing the experiment and writing it up
- Make the circuit shown in figure 41.
- Adjust the voltage source to the correct voltage.
- Place ends A and B of the wires on the copper rod. You will see that the bulb lights up. Copper apparently allows an electrical current to pass. You therefore say that copper is a conductor.
- Your teacher will tell you what other objects you need for this experiment.

1 Copy table 2 into your exercise book.
Make a note in the table of:
a the names of the various objects;
b the substances they are made of.

- Investigate which substances are conductors and which are insulators.

2 Note the results in the table.



◀ figure 41 the circuit for experiment 1

▼ table 2 conductors and insulators

object	made of	conductor or insulator
rod	copper	conductor
etc.		

Instructions for experiments 2, 5 and 7
- To measure the current through a bulb, you connect the ammeter **in series** with the bulb. See 'Skills 8' at the back of the book.
- Ask your teacher to check your circuit before you switch the voltage on.

Experiment 2 Measuring currents 10 min

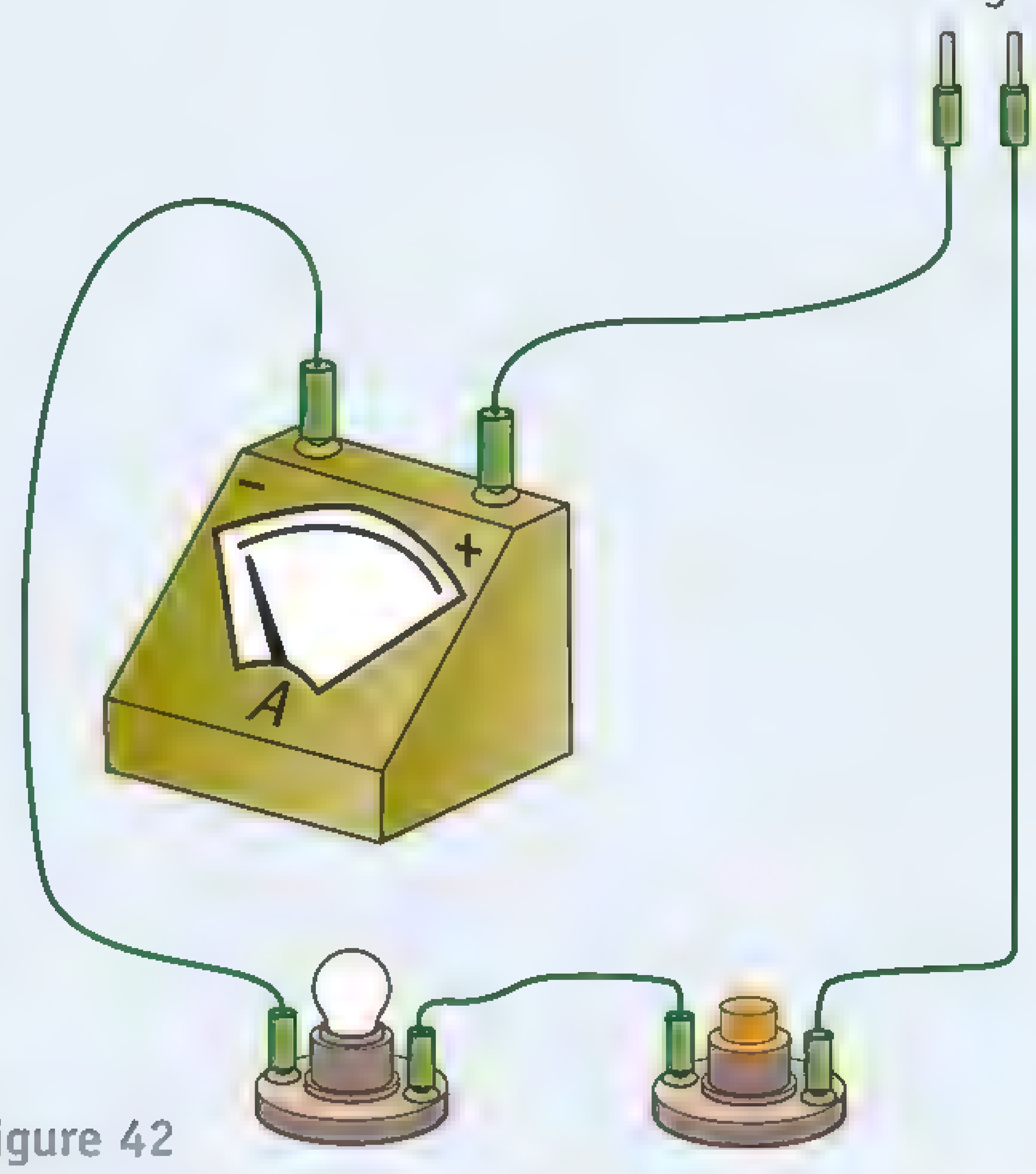
Introduction
You can use an ammeter to measure the current in a circuit. To do that, you connect the ammeter in series with the other components in the circuit.

Aim
You are going to practice measuring currents.

Requirements
- voltage source
- bulb in holder
- four wires
- ammeter
- switch

Doing the experiment and writing it up
- Make the circuit shown in figure 42. Use the least sensitive measurement range. See 'Skills 8' at the back of the book.
- Get the circuit checked by your teacher!
- Adjust the voltage source to the correct voltage.
- Use the ammeter to measure the current through the bulb. Do that both to the left of the bulb and to the right.
- Switch to a more sensitive measurement range if possible before making your final reading of the current value.

1 What is the current through the bulb? Don't forget the units!
2 Does it make any difference whether you measure the current to the left or the right of the bulb?



▲ figure 42
the circuit for experiment 2

Experiment 3 Circuits with bulbs in 30 min

Introduction
There are various different ways of making circuits for bulbs, i.e. connecting the bulbs (which are conductors) to each other and to a voltage source in a way that will let you turn them on and off. Each type of circuit has its benefits and disadvantages.

Aim
You will be learning about three types of circuit in this experiment: the series circuit, the parallel circuit and the mixed circuit.

Requirements
- voltage source
- three bulbs in holders
- six wires

Doing the experiment and writing it up
Making a series circuit
First you are going to make a series circuit with the three bulbs. That is a circuit with no splitting: the current goes from the voltage source to bulb 1 first of all, then to bulb 2, then to bulb 3 and finally back to the voltage source.

1 Draw the circuit diagram for this circuit. Add an annotation: A series circuit with three bulbs.

- Build the circuit according to the circuit diagram. See 'Skills 10' at the back of your book.
- Adjust the voltage source to the correct voltage.

2 Describe how bright the bulbs are: bright, normal or dim.

- Unscrew each of the bulbs in turn (tightening each one again before continuing).

3 What happens to the other bulbs?

- Make a note each time of what happens to the other bulbs.

Making a parallel circuit
You are now going to make a parallel circuit with the three bulbs. This kind of circuit will split three ways: one branch for each bulb. The current splits up into three before reaching the bulbs, so that each bulb gets 1/3 of the current, and then comes together again after the bulbs.

4 Draw the circuit diagram for this circuit. Add an annotation: A parallel circuit with three bulbs.

- Build the circuit according to the circuit diagram. The simplest way is to connect bulb 1 to the voltage source first. Then add the branch for bulb 2 and finally the branch for bulb 3.
- Adjust the voltage source to the correct voltage.

5 Describe how bright the bulbs are: bright, normal or dim.

- Unscrew each of the bulbs in turn (tightening each one again before continuing).

6 Make a note each time of what happens to the other bulbs.

- Dismantle the circuit again.

Making a mixed circuit
You are now going to make a mixed circuit with the three bulbs: this is a combination of a series circuit and a parallel circuit. Instead of three branches, as in the previous circuit, you will now only have two. There are two possible layouts for this mixed circuit, but you only have to try out one of them.

7 Draw the circuit diagram for your mixed circuit. Add an annotation: A mixed circuit with three bulbs.

- Build the circuit according to the circuit diagram.
- Adjust the voltage source to the correct voltage.

8 Describe how bright the bulbs are: bright, normal or dim.

- Unscrew each of the bulbs in turn (tightening each one again before continuing).

9 Make a note each time of what happens to the other bulbs.

- If you have any spare time, try to draw and make the other mixed circuit too.

Experiment 4 Experimenting with a switch 20 min

Introduction
You can use a switch to turn the current on and off. You can use it to turn just a single component on and off, or the whole circuit. That depends on where you include the switch in the circuit.

Aim
In this experiment, you are going to investigate what effect a switch has at various points in a circuit. The question you are studying is:
How can you use a switch (a) to turn a single component of a circuit on and off, and (b) to turn various circuit components on and off at the same time?

Requirements
- voltage source
- three bulbs in holders
- eight wires
- switch

Doing the experiment and calculations
- Make a parallel circuit with the three bulbs.
- Adjust the voltage source to the correct voltage.
- Check that the three bulbs are working normally.

1 Make a drawing of the circuit you have constructed. Number the wires you have used from 1 to 6.

- Connect the two remaining wires to the switch.
- Replace wire 1 by the switch plus its two wires (figure 43).
- See what happens when you use the switch to turn the current on and off.

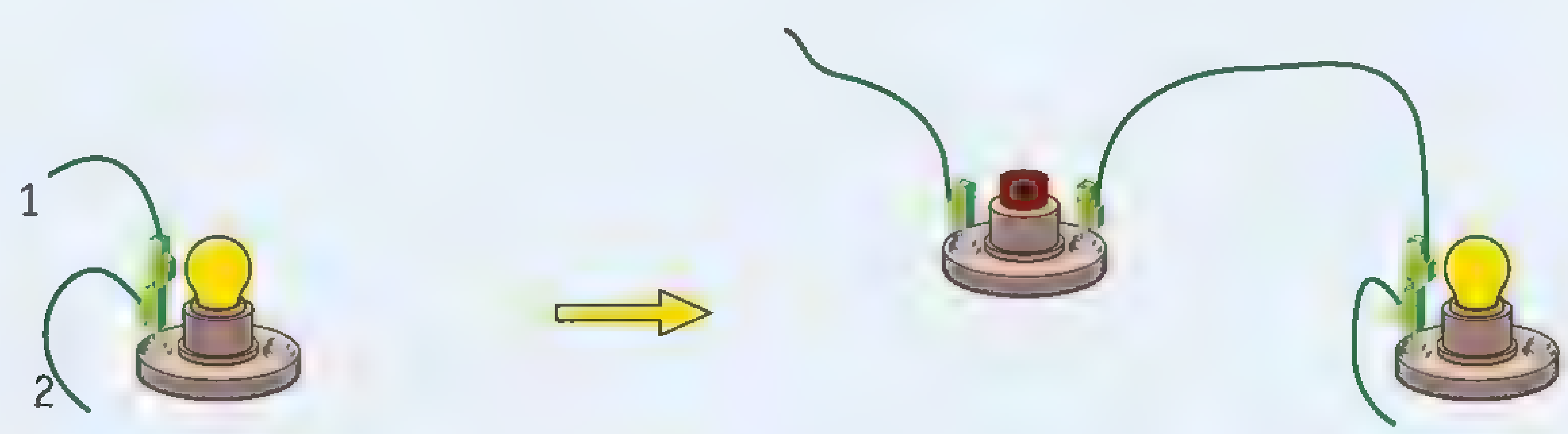
2 Draw the circuit diagram for the circuit you have made.
State which bulbs go out when you turn the switch to OFF.

- Remove the switch and its two wires and connect wire 1 up again.
- Now use the switch with its two wires to replace wire 2.
- See what happens when you use the switch to turn the current on and off.

3 Draw the circuit diagram. Make a note of which bulbs go out when you turn the switch to OFF.

- Then do the same for wires 3 to 6.

4 Make the drawings and note your observations in your exercise book.
5 Finally, give the answer to the question you are studying.



▲ figure 43
This is how you can add a switch instead of wire 1.

Experiment 5 The current in a series circuit 20 min

Introduction
You can use an ammeter to measure the current in a series circuit. You can measure the current at various points: between the voltage source and the first circuit component, between the circuit components, and after the final circuit component.

Aim
You are going to investigate what rule applies for the current in a series circuit.

Requirements
- voltage source
- two bulbs in holders
- five wires
- ammeter
- switch

Doing the experiment and writing it up
- You are about to make a series circuit with two bulbs and an ammeter.

1 Draw the circuit diagram for this circuit.

- Get your teacher to check the circuit diagram. Then construct the circuit.
- Adjust the voltage source to the correct voltage.
- Read the value for the current. First use the ammeter's least sensitive measurement range. Then switch down to a more sensitive measurement range if possible.
- Measure the current three times: before bulb 1, between bulbs 1 and 2, and after bulb 2.

2 Make a note of the results in your exercise book. Don't forget the units!
3 What is the rule for the current in a series circuit?

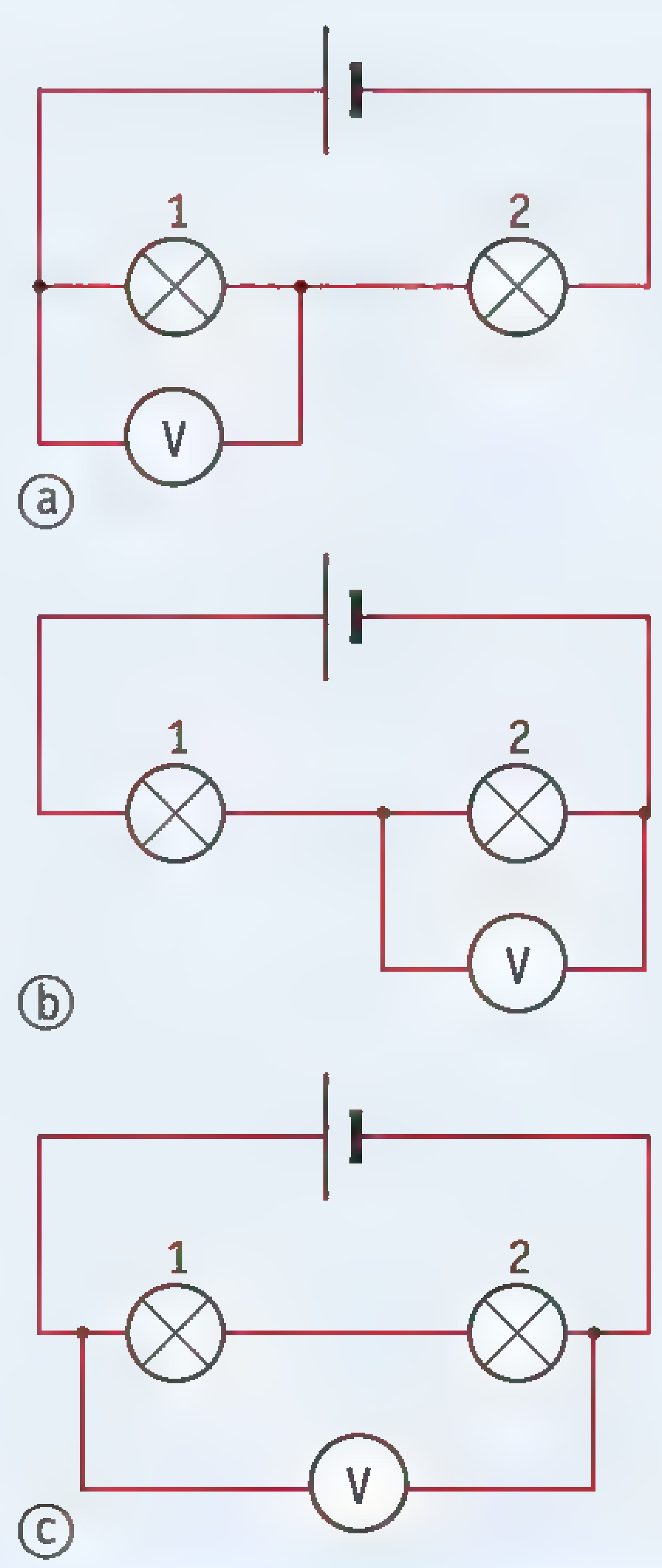
Experiment 6 The voltage in a series circuit 20 min

Introduction
You can use a voltmeter to measure the voltage in a series circuit: across each circuit component individually, or across all the circuit components together.

Aim
You are going to investigate what rule applies for the voltages in a series circuit.

Requirements
- voltage source
- two bulbs in holders
- five wires
- voltmeter

Doing the experiment and writing it up
The voltage across bulb 1
- Make the circuit shown in figure 44a.
- Adjust the voltage source to the correct voltage.
- Read the voltage. First use the voltmeter's least sensitive measurement range. Then switch down to a more sensitive measurement range if possible.



◀ figure 44 the three circuits in experiment 6

1 Copy and complete:
The voltage across bulb 1 = ... V.

The voltage across bulb 2
- Make the circuit shown in figure 44b.
- Read the voltage.

2 Copy and complete:
The voltage across bulb 2 = ... V.

The voltage across both bulbs together
- Make the circuit shown in figure 44c.
- Read the voltage.

3 Copy and complete:
The voltage across bulbs 1 and 2 together = ... V.
4 Compare the voltage of the voltage source against the voltages that you have measured.
What do you notice?
5 What is the rule for the voltages in a series circuit?

Experiment 7 The current in a parallel circuit 20 min

Introduction
You can use an ammeter to measure the current in a parallel circuit. You can measure the current at various points: in the branches and in the undivided parts of the circuit.

Aim
You are going to investigate what rule applies for the current in a parallel circuit.

Requirements
- voltage source
- two bulbs in holders
- six wires
- ammeter
- switch

Doing the experiment and writing it up
- Figure 45 shows a parallel circuit with an ammeter drawn in at four positions. In this experiment, you are going to measure the current at these four places.

1 What do you think: what relationship will there be between the currents you will measure at these four points?

- Construct the circuit shown in figure 45. Connect the ammeter at point 1.
- Adjust the voltage source to the correct voltage.
- Read the value for the current. First use the ammeter's least sensitive measurement range. Then switch down to a more sensitive measurement range if possible.

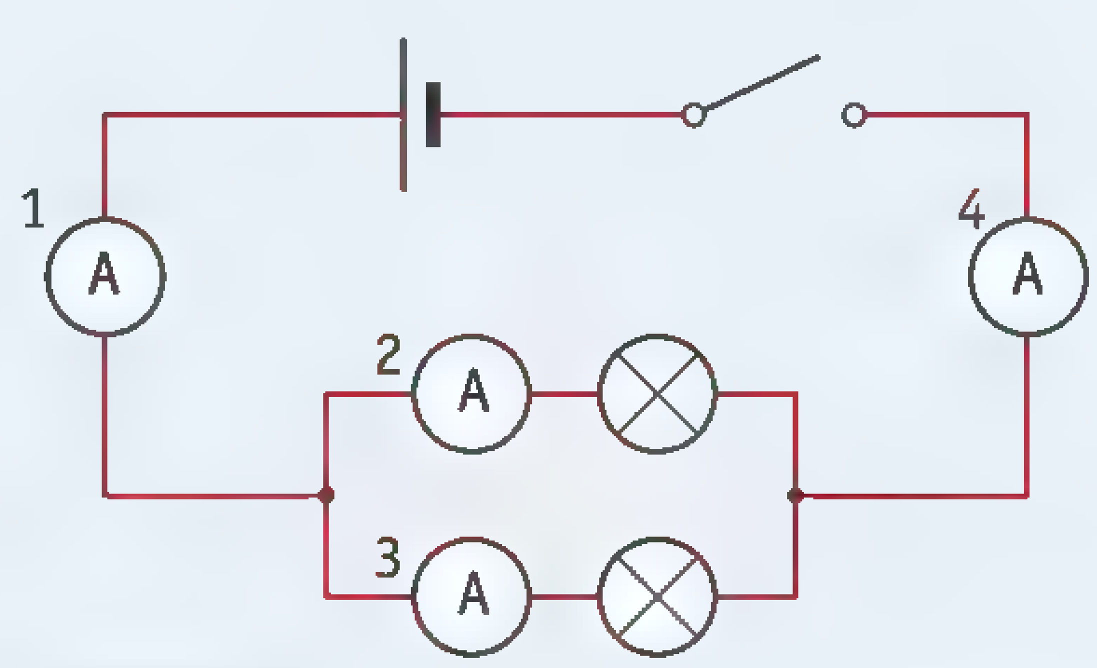
2 What is the current at point 1?

- Change the circuit by connecting the ammeter at point 2.
- Measure the current at point 2 as accurately as possible.

3 What is the current at point 2?

- Then also measure the current at points 3 and 4.

4 What is the current at points 3 and 4?
5 Take another look at the predictions you made for question 1.
Were your predictions correct?
6 What is the rule for the currents in a parallel circuit?



▲ figure 45
the circuit for experiment 7

Experiment 8 Producing a design – a fog light circuit 45 min

Introduction

Imagine: fog lights have to be fitted to a car. The intention is that it should only be possible to turn the fog lights on if the car's normal lighting is already on. For this assignment, you are the designer who has to come up with a feasible solution.

Aim

In this experiment, you will be thinking up and testing a circuit for the car lighting, including the fog lights. Your prototype must meet the following design requirements:

Design requirements

- The circuit consists of five bulbs and two switches.
- Bulbs 1 and 2 represent the headlights.
- Bulbs 3 and 4 represent the rear lights.
- Bulb 5 represents the rear fog light.
- The headlights and the rear lights can be turned on and off using switch 1.
- The rear fog light can be turned on with switch 2, but only if the headlights and the rear lights are on.

Requirements

For this experiment, you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up

- Think how you can carry out the experiment. What circuit are you going to build, what practical equipment will you need for it, and how are you going to test whether the circuit is working properly?

1 Make a work plan for this experiment.

- The work plans will be discussed with the rest of the class at the next lesson. If necessary, you can make improvements to your own work plan after that.
- Build the circuit and test it.

2 Make a test report that includes:
- **a** a circuit that meets all the design requirements;
- **b** the test you have carried out and the corresponding results;
- **c** any changes that you made to your circuit.

Test Yourself

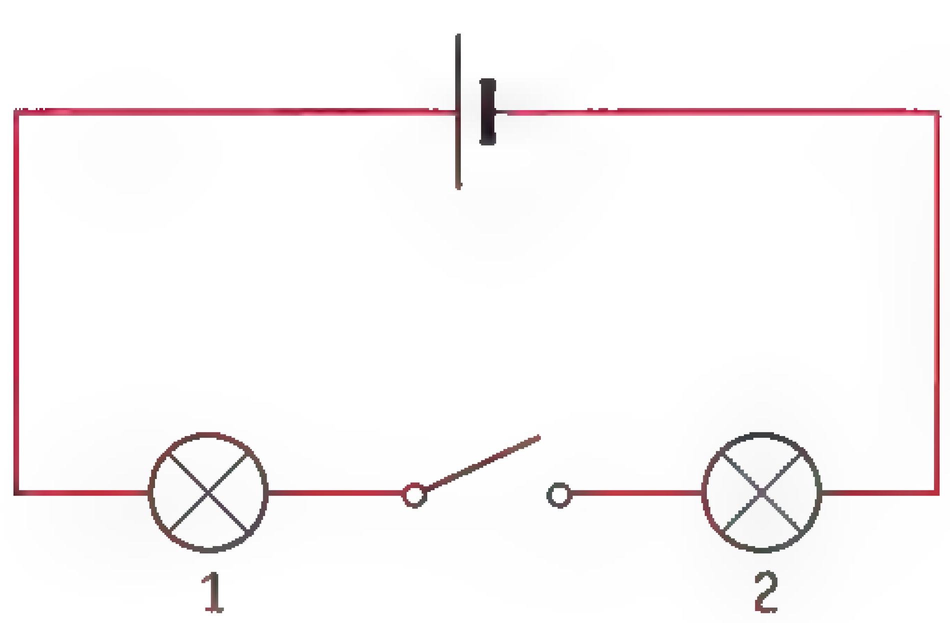
You can also do questions 1 to 16 on the computer.

1 Seven substances are listed below:
aluminium – glass – graphite– copper – PVC – rubber – steel
List these substances in two rows: the conductors on the left and the insulators on the right.

2 Copy and complete:
a 0.125 A = ... mA
b 14 mA = ... A
c 0.078 A = ... mA
d 300 mA = ... A
e 0.0082 A = ... mA

3 Naomi has an ammeter with three measurement ranges: 0-50 mA, 0-500 mA and 0-5 A.
The current she wants to measure is somewhere between 80 and 120 mA.
Which is the best measurement range for her to use?
A 0-50 mA
B 0-500 mA
C 0-5 A

4 Figure 46 shows you a circuit with a battery, two bulbs and a switch. The switch is open.
a Is bulb 1 lit?
b Is bulb 2 lit?

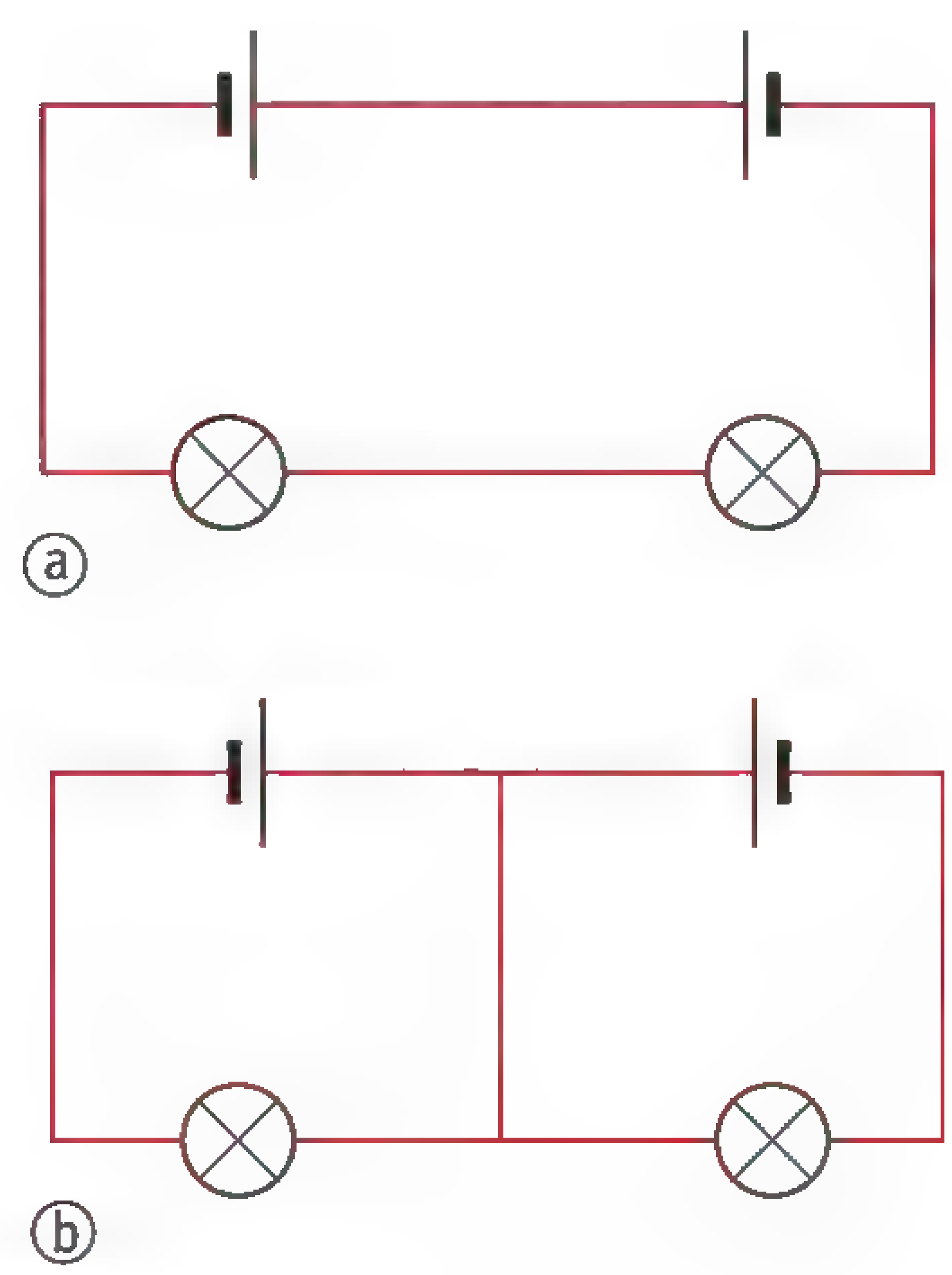


▲ figure 46
a circuit with two bulbs

5 Figure 47 shows a voltmeter.
Read the value of the voltage as accurately as possible and make a note of it.

▲ figure 47
What voltage does this voltmeter indicate?

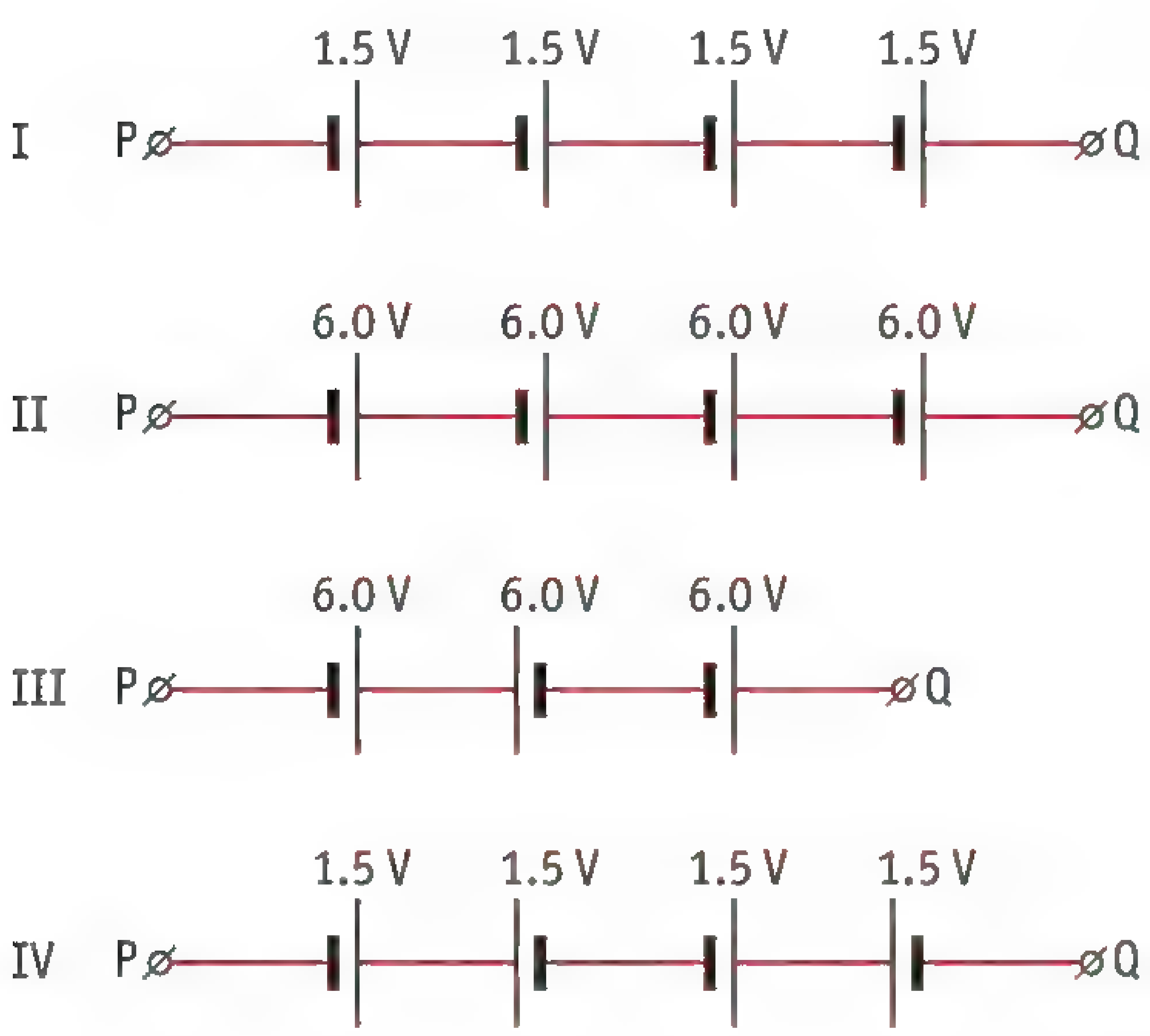
6 A particular type of bulb is at normal brightness when the voltage across it is 3.0 V and dim when the voltage is across it 1.5 V. Max has made a circuit using two of these bulbs and two 1.5 V batteries. See figure 48a.
a How bright will the bulbs be in figure 48a: normal, dim, or not lit at all?
b Max adds another wire so that he gets the circuit shown in figure 48b.
How bright will the bulbs be in figure 48b: normal, dim, or not lit at all?



▲ figure 48
Max's circuits

Nova © Uitgeverij Malmberg

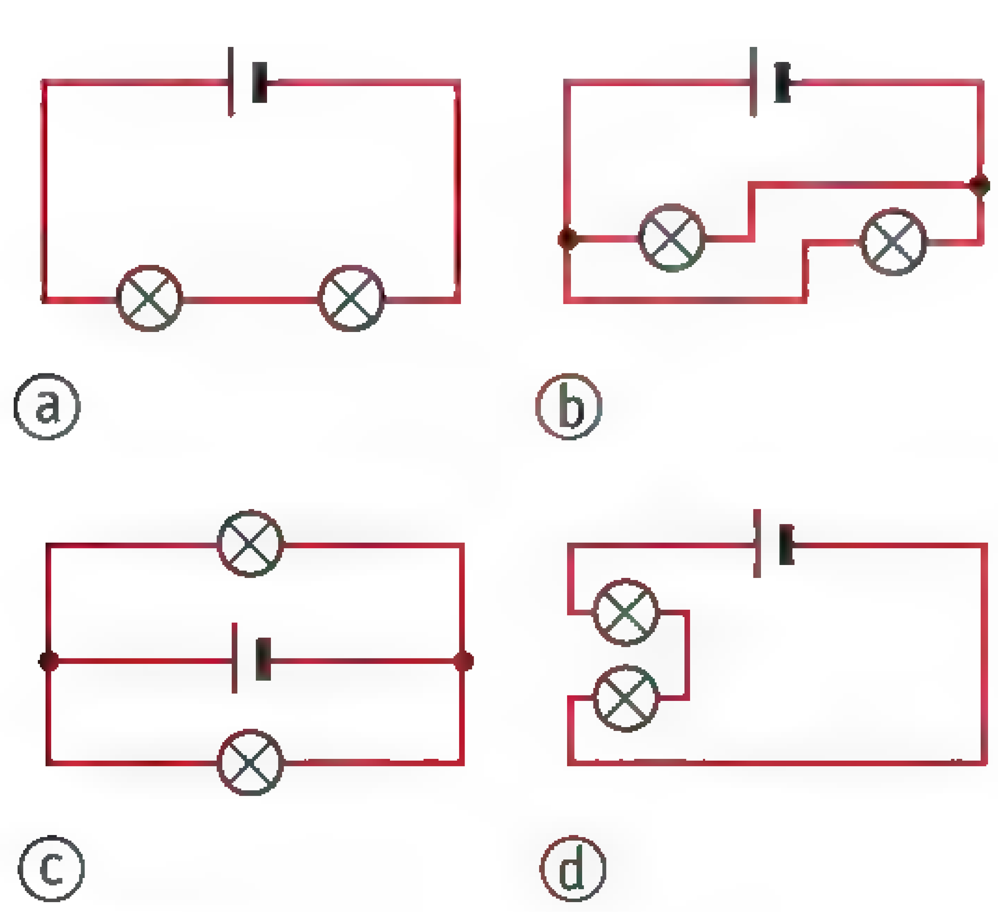
7 Figure 49 shows four ways of connecting batteries together.
In which circuit (or circuits) do you get a voltage of 6.0 V between P and Q?



▲ **figure 49**
Connecting batteries together.

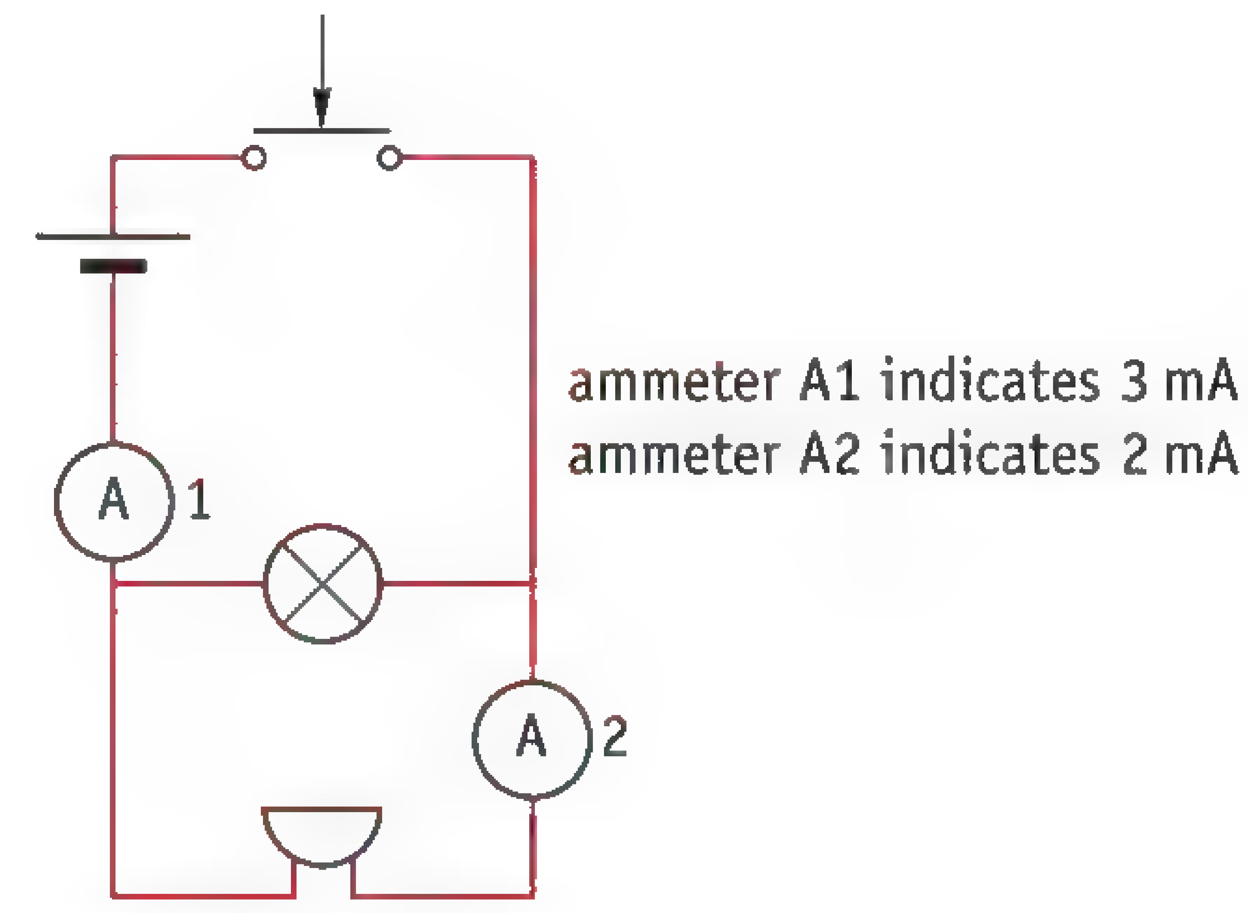
8 To recharge a mobile, you use an adapter that is plugged into the mains socket.
What is one essential component of an adapter?
A a battery
B a dynamo
C a generator
D a transformer

9 Figure 50 shows four circuits.
Which of these four circuits are parallel circuits?



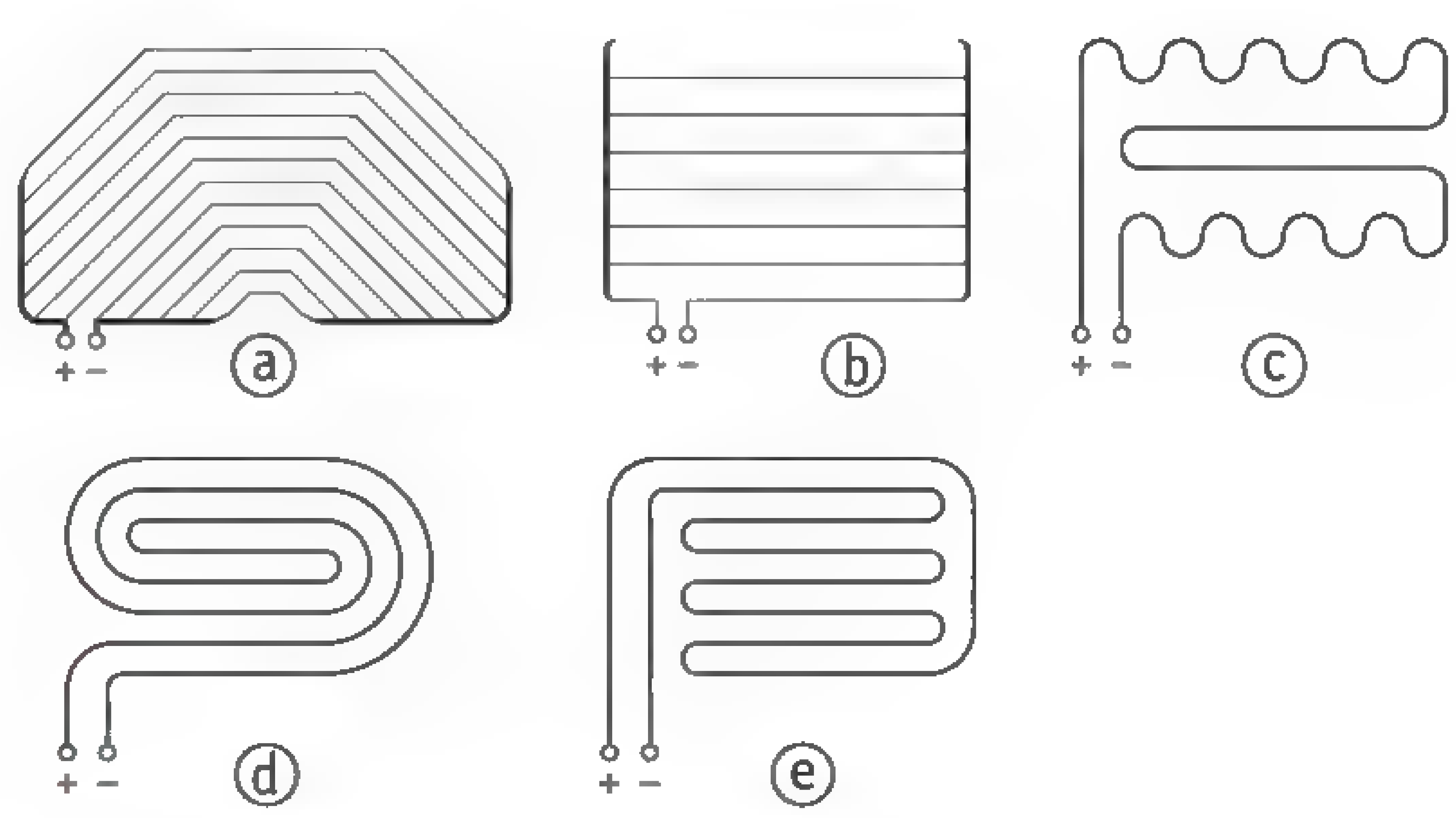
▲ **figure 50**
four circuits

10 See figure 51. A buzzer and a bulb are connected to a battery. When the switch is pressed, the buzzer makes a noise and the bulb lights up.
There are two ammeters connected in the circuit.
a What current is going through the buzzer?
b What current is going through the bulb?

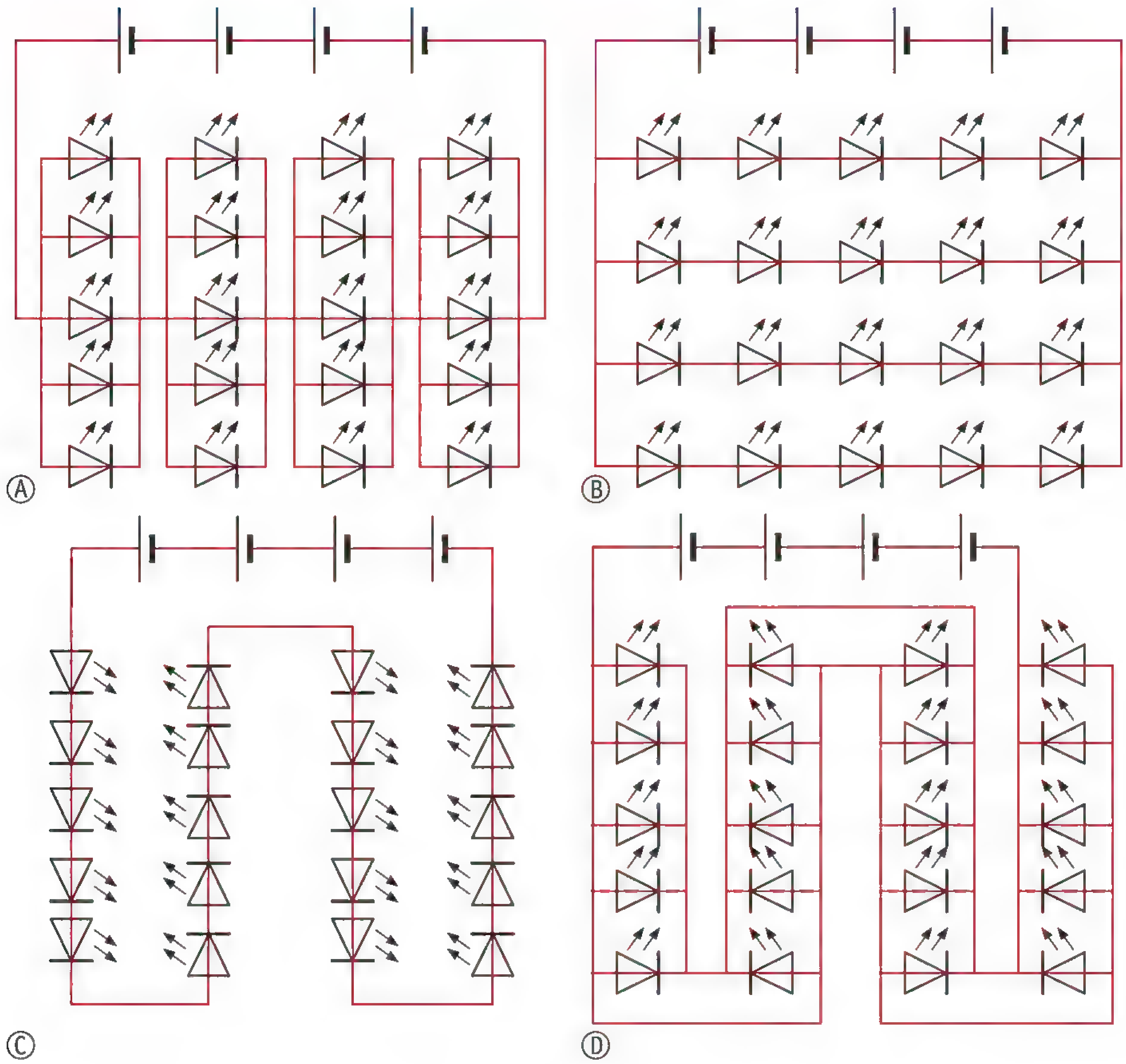


▲ **figure 51**
bulb and buzzer

11 The rear window heater in a car makes sure that the rear window is warm so that it does not get covered in condensation. The heating wires in the window can be connected up in different ways. Figure 52 shows you five examples.
a In which drawing (or drawings) are the heating wires connected in series?
b In which drawing (or drawings) are the heating wires connected in parallel?
c Take a good look at drawing B. Which section of heating wire has the greatest current flowing through it?



▲ **figure 52**
five rear window heater configurations

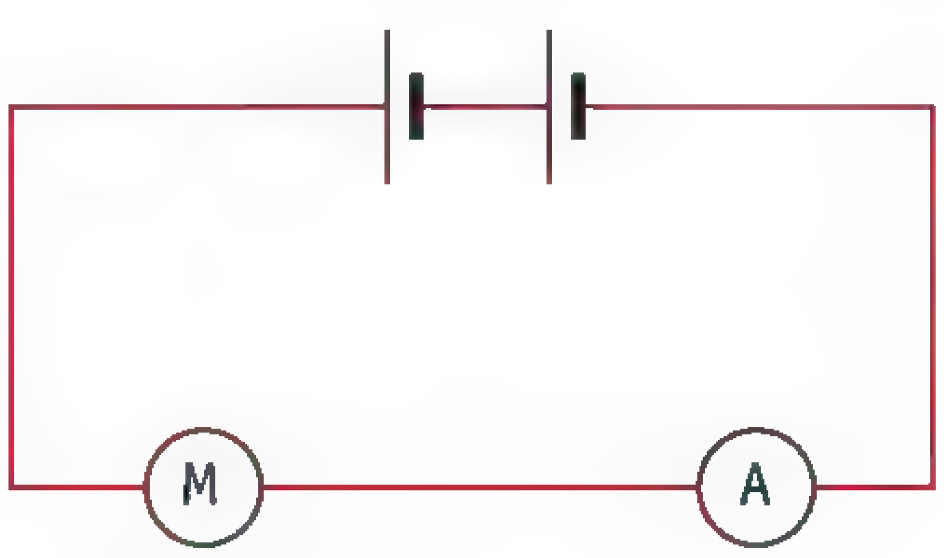


▲ figure 53
four circuits for Christmas lights

12 At Nigel's house, they have outdoor Christmas lighting with twenty LED lights. If any single LED breaks, a row of five LED lights goes out. The Christmas lights run on four batteries.
Which diagram in figure 53 could represent this Christmas lighting?

13 A bulb is marked with the letters 230V/23W/50Hz.
a What is the power consumed by the bulb if it is running at its correct voltage?
b To what voltage should the bulb be connected?

14 Emma is making a circuit with an electric motor (figure 54). She is using two 1.5 V batteries as the voltage source. When the current is switched on, the ammeter registers 20 mA.
Work out the power of the motor.



▲ figure 54
Emma's circuit

15 The packaging of a car bulb says 12 volts/5 watts. Calculate the size of the current through the bulb if it is connected up to a voltage of 12 V.

16 Say whether the following statements are true or false.

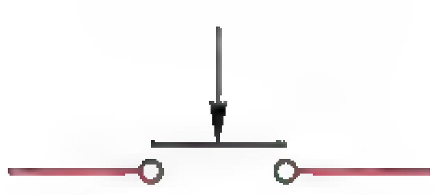
- **a** All metals conduct electric currents, but some metals are better conductors than others.
- **b** A transformer can be used to convert mains voltage down to a safe low voltage.
- **c** If you measure the current in a parallel circuit, you will find that it is the same everywhere.
- **d** The lower the power of a mobile, the more quickly its batteries will run out.

17 Draw the circuit diagram symbols for:

- **a** a battery.
- **b** an electric bell.
- **c** an electric motor.
- **d** a switch (open).
- **e** an ammeter.

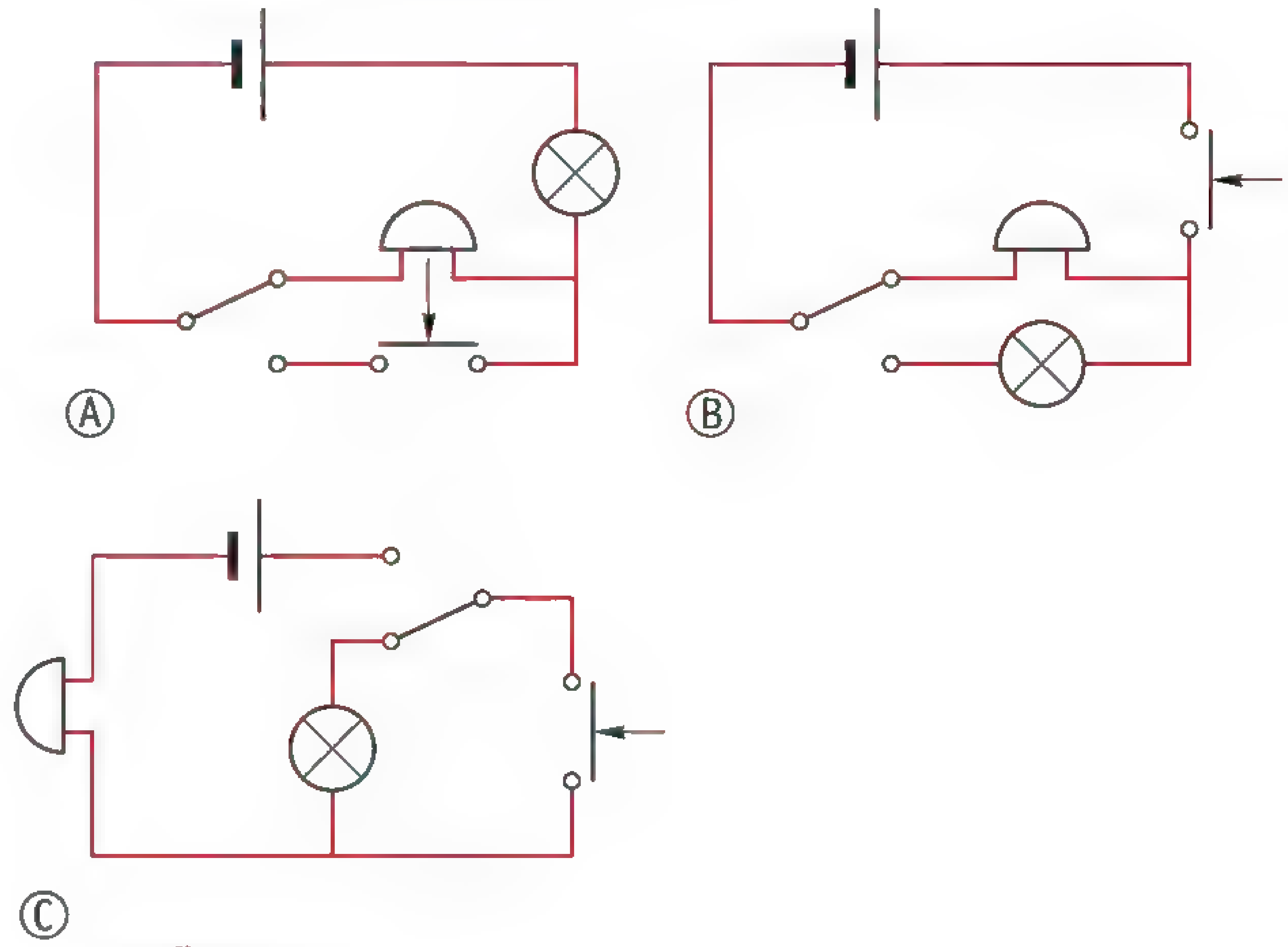
18 Tom does not like it when people come into his room unexpectedly. He has therefore made a separate bell for his room. The wires from the doorbell go to a battery and a bell.

- **a** Draw the diagram for this circuit. In figure 55 you can see what the circuit symbol for the doorbell (a pressure switch) looks like.



▲ figure 55
the circuit symbol for a pressure switch

- **b** Tom has a baby sister who needs a nap in the afternoon. The bell is not allowed to ring then. He changes the circuit so that a bulb can be included instead of the bell. He uses a two-position switch for this. Tom has set the circuit up so that the bell is connected in one position and the bulb is connected in the other.
- **c** Which of the diagrams in figure 56 correctly represents Tom's circuit, A, B or C?



▲ figure 56
Which is Tom's circuit?

19 You need worksheet 5-2 for this exercise.
The worksheet shows you a drawing for the Olympic fencing competition. The electrical system for registering the hits is interesting. The lights show you whether or not a hit was scored. The fencers are connected to the equipment with electric wires.
Design a score registration system yourself. In this system, bulb A must light up for a moment if one fencer is hit and bulb B must light up for a moment if the other fencer is hit. You have two voltage sources available.
Think about the following beforehand:

- **a** what materials must the fencers' weapons and jackets be made of?
- **b** how many wires must there be in the cables connected to the fencers, and how must they be connected?
  Draw your circuit diagram on the sketch on the worksheet.

20 The screen of a mobile phone turns off if you do not use the phone for a little while.

- **a** Explain what then happens to the mobile's power consumption.
- **b** Explain why turning the screen off is a useful feature for you.

Nova © Uitgeverij Malmberg

A solar energy competition

It is the fifth day of the World Solar Challenge. The solar-powered car of the Nuon Solar Team from Delft is in a comfortable second place. And then – with the finishing line almost in sight – fate threatens to take a hand. "We hadn't predicted that final bridge," says Mike Hoogstraten, the team's technical manager, "and the battery was virtually flat!" In a situation like that, the driver only has one option: to slow down and cross your fingers that you don't come to a complete standstill.

Every two years, a few dozen teams gather for the *World Solar Challenge*, a race for solar-powered vehicles through the Australian outback. The route goes from Darwin in the north to Adelaide in the south, covering a distance of more than 3000 kilometres. The race is particularly tough for the drivers: for five or six days, they are enclosed in a tiny little cab in which the temperature can get up to 50 °C or more.

The latest edition of the race started on 16 October. This year there were two Dutch teams: the *Nuon Solar Team* from Delft University and *Solar Team Twente* from the University of Twente. The challenge was particularly tough for the team from Delft, who had a lot to of expectations to live up to as the *World Solar Challenge* had been won by teams from Delft four times before.

“Australia is a sunny country, but the sun’s not going to be shining all the time.“

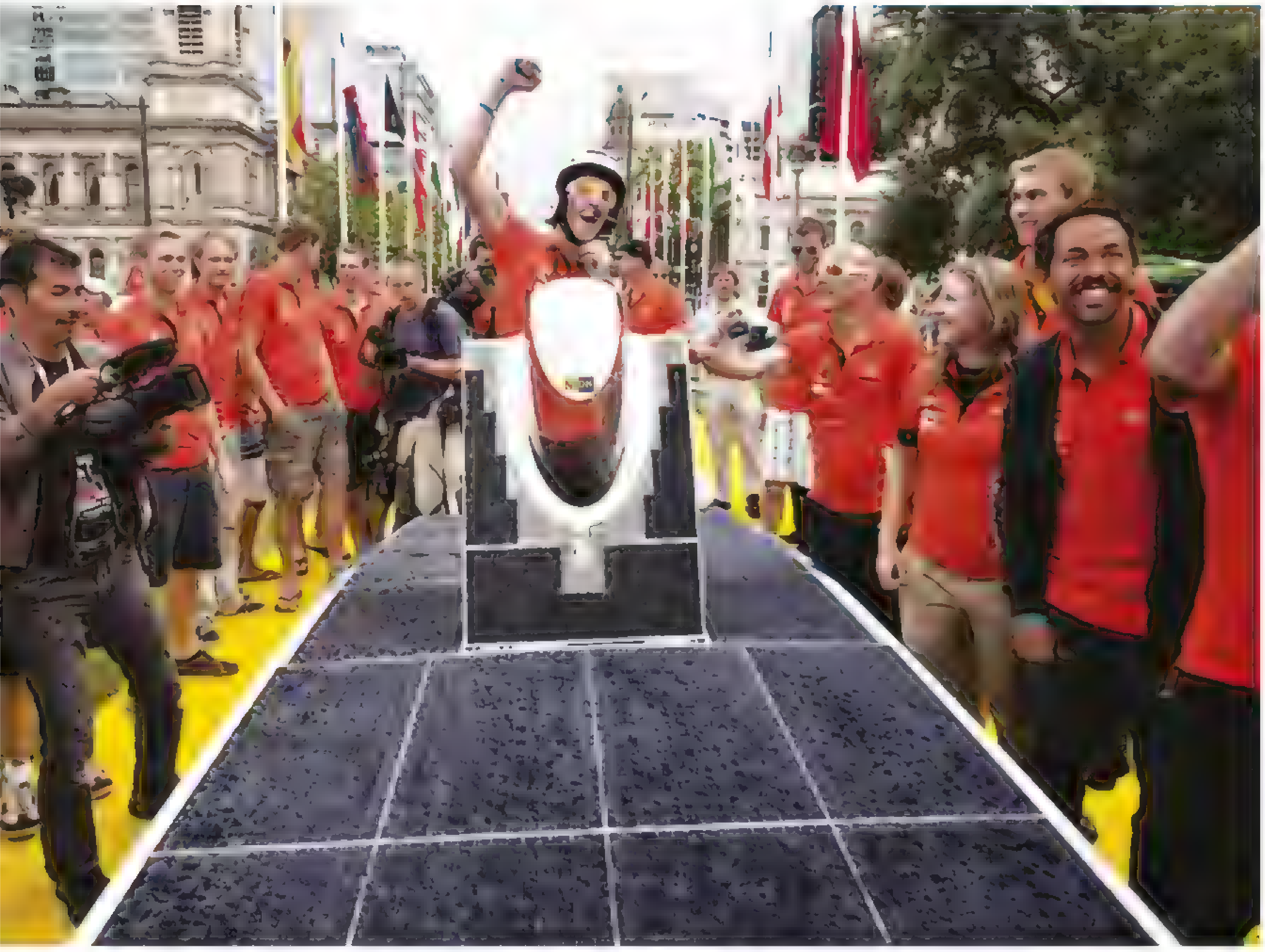
Driving on sunlight

The vehicles taking part in the *World Solar Challenge* run entirely on solar energy. The *Nuon Solar Team*’s car *Nuna6* has 1690 tailor-made silicon cells for the purpose, with an overall surface area of 6 m². When the Sun is shining brightly that is more than enough for it to reach speeds of 110 km/h. The vehicles are not allowed to go faster than that: like all traffic, they have to observe the Australian speed limits.

In sunny weather, the solar cells generally produce more electrical energy than is needed at that time. However the energy is not lost: the excess is stored temporarily in batteries. That is very useful if there is a shortage of energy later in the day, for example because the Sun is suddenly obscured by clouds. The energy that has been saved up in the batteries can then be used to power the solar vehicle.

Recharging and discharging

The batteries also play a key role at the start. Getting up to speed quickly requires a lot of power – a lot of energy over a relatively short time. Car drivers know all about that: getting quickly off the mark guzzles a lot of petrol. The same is true for a solar-powered car (though it is electrical energy rather than petrol that is being guzzled). Because solar cells are only able to supply a limited amount of power, the batteries have to help a lot when getting the car moving.



The batteries are therefore charged up in the morning before the start, using the solar cells. The competing teams also try to get their batteries fully recharged during the stops. They park their vehicles at angles designed to catch as much sunlight as possible. The more electrical energy they can store in their batteries, the better their chances in the race.

However, continually recharging and discharging the batteries can be a risky business. One of the competing teams this year had a fire in the batteries. A lot of the solar-powered cars therefore have a special Battery Management System that is constantly monitoring the battery charge. The system makes sure that the batteries cannot become overcharged, or indeed discharged too far, as it is possible for them to catch fire in either situation.

Strategic driving

A well-designed solar car is no guarantee that you will win the race. It also requires intelligent driving. When the weather is not very sunny, you cannot drive at full speed all the time. The batteries would then be exhausted way before the finish. Going too slowly is not a good idea either, of course. You want to make the best possible use of the energy accumulated in the batteries.

The successful teams therefore adopt a carefully thought-out strategy that the people in the team car following the solar vehicle are constantly working on. The electronics in the solar-powered car passes data on to the team members about the energy production of the solar cells and the charge levels of the batteries. They also monitor the weather forecasts closely. They use all this information to work out the optimum speed for the solar car. This is then passed on to the driver.

Right from the very first day, for instance, *Solar Team Twente* was making allowances for the fact that it could be cloudy at the end of the race. “Because the final day is expected to be cloudy – or it may even be raining – we may only be able to drive on the batteries then. So energy has to be saved up now,” wrote Helga van Leur in her blog. She is the meteorologist travelling with the team from Twente. “Yes, Australia is a sunny country, but, the sun’s not going to be shining all the time.”

Problems for Umicore

The Umicore Solar Team from Belgium had a major setback in the World Solar Challenge last Friday. The team was in a very creditable fourth place when fire broke out in one of the batteries about 200 km from the finish. The driver and a number of team members were taken to hospital for a check-up because they had inhaled the smoke, but they were soon allowed to leave again. After emergency repairs, the vehicle was able to continue on Saturday with the spare batteries.

Finish

The team from Twente finally finished fifth. The winners were a team from Tokai University in Japan, one hour ahead of the *Nuon Solar Team* from Delft. The calm and collected approach of the driver Javier Sint Jago let the Delft team hold on to their second place, despite the unexpected final bridge. “Everything on the screens was in the red,” said Javier, talking about the tense moment at the end of the race. “So I thought, ‘Oh no – foot off the pedal!’ ” The *Nuna6* crept up over the bridge and finally got over the finishing line with nothing left in its batteries.

Second and fifth places were excellent results, of course, but there’s always room for improvement. There are undoubtedly enough enthusiastic students in Delft and Twente to make sure that the next *World Solar Challenge* will also be an exciting high-tech event.

Exercises

1 During the stops, the solar-powered cars are often placed at an angle.
- **a** In which direction should the driver tilt the solar-powered vehicle?
- **b** Why does that position mean that the batteries will be recharged more quickly?

2 Explain why the batteries of a solar vehicle are switched on:
- **a** when the Sun disappears behind clouds.
- **b** when the solar car drives up a hill.
- **c** when the driver is going to overtake another vehicle.

3 Javier Sint Jago said that he ‘took his foot off the pedal’ for the last bridge.
Explain:
- **a** exactly what the driver meant by ‘taking his foot off the pedal’.
- **b** why he had to do that.

***4** Imagine: there are three switches in the electrical system of a solar-powered car:
- switch 1: between the solar panels and the batteries;
- switch 2: between the solar panels and the motor;
- switch 3: between the batteries and the motor.

Which switches are open (ON) and which are closed (OFF):
- **a** when the batteries have been charged as fully as possible before the competition?
- **b** when the car is driving quickly uphill during the competition?
- **c** when the car is driving at 110 km/h on a flat road in good weather?

Note:
Delft won the *World Solar Challenge* for the fifth time in 2013.

Nova © Uitgeverij Malmberg

6

Movement

Sport and traffic

Movement is key in sports and in traffic. That is why all kinds of techniques have been developed for recording, analysing and describing motion. The results are used to make traffic safer and to improve sporting performance.

1 Recording movements

Many movements are so quick that you cannot follow them properly with the naked eye. However, people do still sometimes want to know how that movement proceeds. For example, high-jumpers and gymnasts can use that information to improve their performance. That is why various methods have been developed for recording and analysing motion.

Filming motion

You can record a motion by filming a moving object with a video camera. The camera then stores a **video recording**, a series of images that are made at short intervals (figure 1). Many video cameras make recordings at 30 frames (pictures) per second. The time between successive pictures is 1/30 s (or approximately 33 ms).

▲ figure 1
a series of pictures from a video recording

There are computer programs that you can use to analyse a video recording one frame at a time. These kinds of programs often offer the option of 'clicking' on an object whose motion you want to track. The program then collects data about the location and speed of the object and presents it in a table or graph.

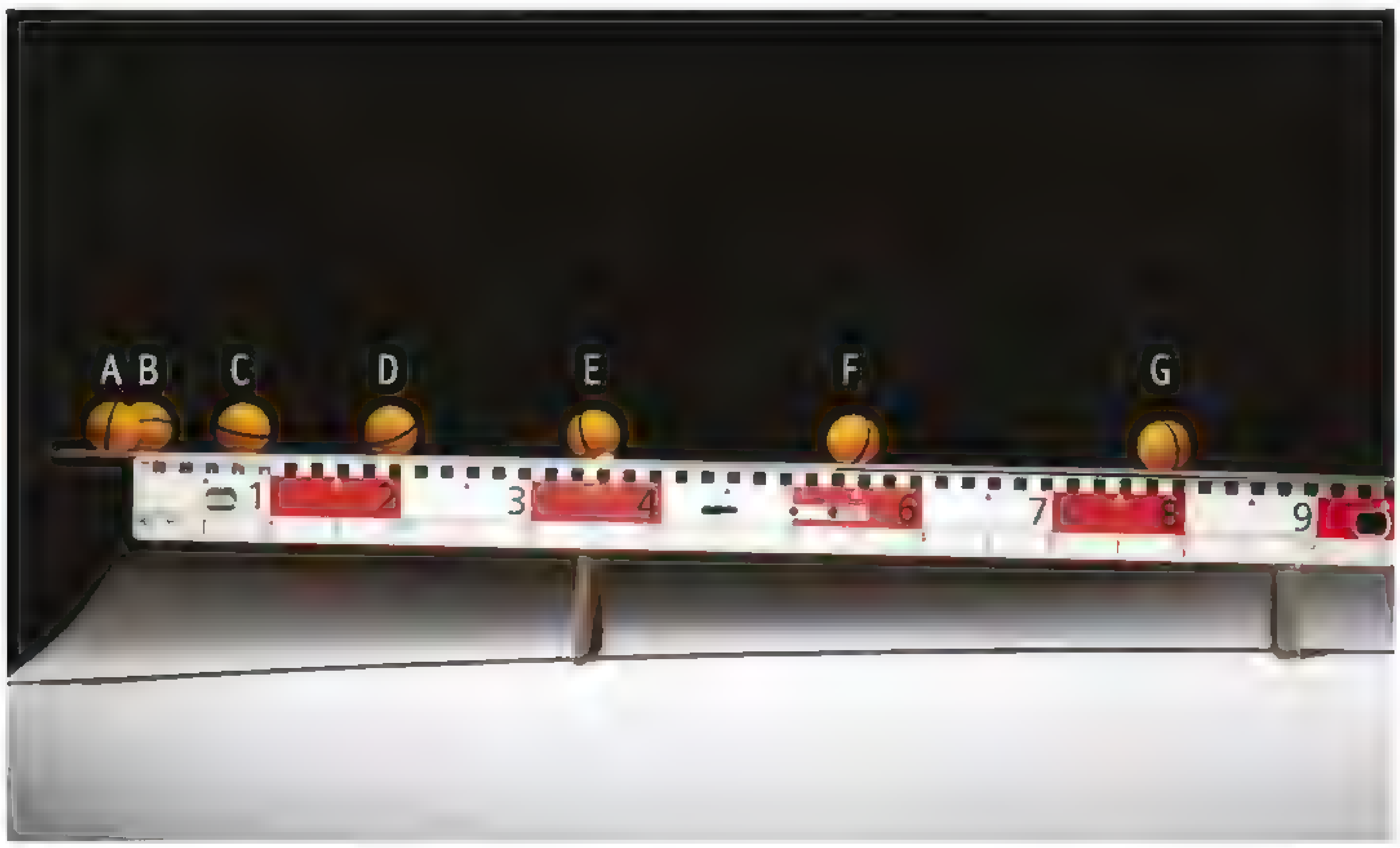
Not all video recordings can be analysed that way. To get good results, you need a recording in which the object is moving past a stationary camera. The recording also has to show a yardstick or other object with known dimensions that allows the **scale** of the image to be determined. Finally, you have to know how many frames per second there are in the recording.

Making stroboscopic photos

Experiment 1

You can also record a motion by taking a **stroboscopic photo.** This type of photograph is taken in a darkened room, using a stroboscope as the only light source. This is a light that gives very short flashes of light at regular intervals. There is a knob on the stroboscope that lets you adjust the time between successive flashes.

The camera shutter remains open throughout the movement. Every time that the light flashes, the progress of the movement at that moment is recorded. All the individually recorded images appear together on a single photograph. Figure 2 gives an example. You can easily see exactly where the object was at each moment.



▶ **figure 2**
a stroboscopic photograph of a rolling ball

A video recording of a movement consists of a whole series of images. You can use a computer program to process those images into a single combined picture. That gives you something that is very similar to a stroboscopic photo. Figure 3 gives an example.

▶ **figure 3**
a 'stroboscopic photo' generated from a video recording

Completing a distance-time table Experiment 2

It is often a good idea to make a **distance-time table** when you are analysing a linear (straight-line) motion. The data for this kind of table can be obtained from a video recording or a stroboscopic photograph. You need to know:
- the time intervals between the individual 'snapshots';
- the actual distances represented in the photographs.

In the motion shown in figure 2 the interval between successive flashes of light is 0.5 s. The position of the ball can be read off the measuring tape. Always look at the same side (the right-hand side) of the ball when doing so, as the ball is moving to the right.

Once you know all this, you can fill in the distance-time table.
- The motion starts at A. The right-hand side of the ball is exactly aligned with the zero on the ruler. You therefore enter the following into table 1 for point A: time = 0 s and distance = 0 cm.
- You then read off where the ball is for B: 3 cm. You note the following in the table for point B: time = 0.5 s and distance = 3 cm.
- After that, you read off where the ball is for C: 10 cm. So the entry for point C says: time = 1.0 s and distance = 10 cm.

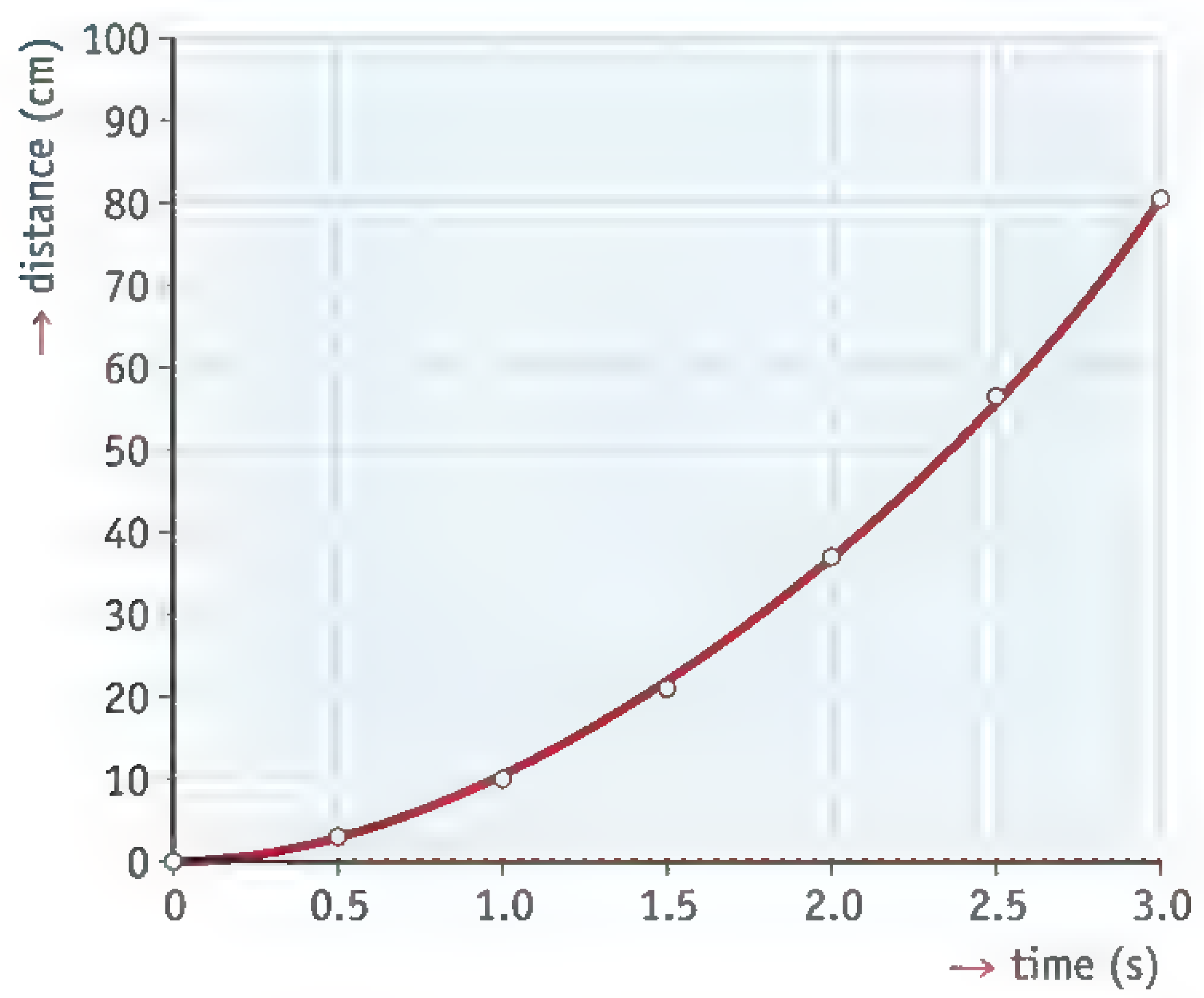
Work out for yourself how the rest of table 1 should be filled in.

▼ table 1 a distance-time table

	time (s)	distance (cm)
A	0	0
B	0.5	3
C	1.0	10
D	1.5	
E		
F		

Drawing a distance-time graph

You can use the data from a distance-time table to draw a graph of the movement. This kind of graph is called a **distance-time graph** or (x,t) graph. The letter x represents the distance and the t stands for time. The (x,t) graph for the motion show in figure 2 has been drawn in figure 4. You can use an (x,t) graph to read off the corresponding position for any moment in time, and vice versa.



▶ figure 4
the (x,t) graph of the rolling ball

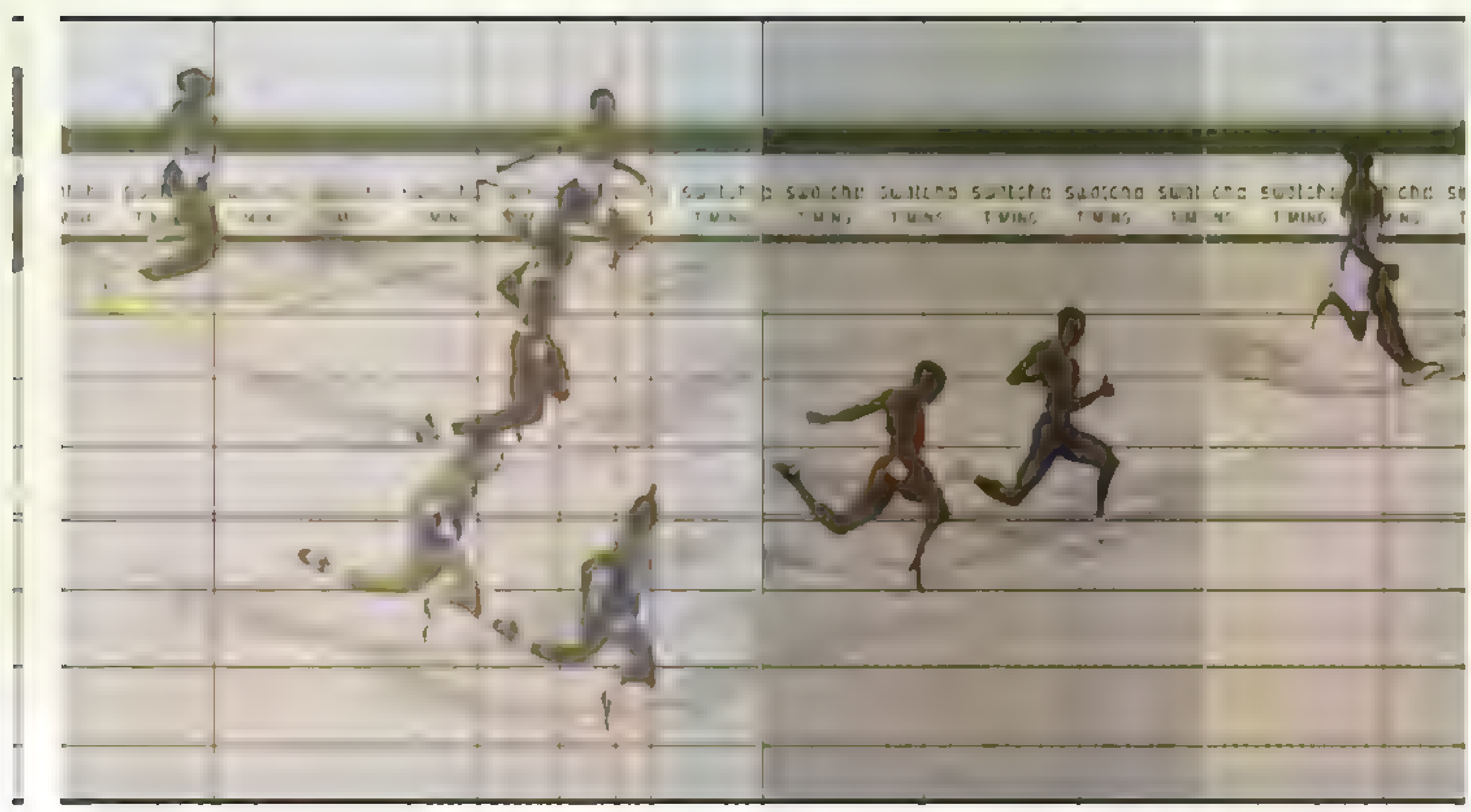
 © Uitgeverij Malmberg

Plus Photo finishes

In the 100 metres, the sprinters often cross the finishing line at almost the same time. Sometimes the judges need a photograph of the finish to determine who won the race. The photo shows clearly in what order the athletes crossed the finishing line.

A photo-finish picture is made using a special camera. A screen with a vertical slit is placed in front of the camera lens through which a narrow strip of the track can be seen at the finishing line. If you take a photo with the camera, you get a narrow image showing only the finishing line (figure 5a).

A modern photo-finish camera can take thousands of photographs every second. Each image is just a single pixel wide. The photo-finish picture consists of a whole series of these photographs next to one another (figure 5b). Together, these images make up the photo finish. On the right, you can see the athlete who reached the finish first; the athlete who was last is on the left.



a b

▼ **figure 5**
A photo-finish consists of a series of images placed next to one another. On the left you can see one single image; the whole finishing photo is on the right.

Exercises

1 Answer the questions below.

- **a** How can you record a rapid motion? State two methods.
- **b** What is the name for a device that gives flashes of light at regular intervals?
- **c** What is the name for a photograph taken using this kind of light?
- **d** What do we mean by the '(x,t) graph' of a motion?

2 Sharon has made a video recording of a falling basketball. Now she would like to make a distance-time table for that movement.
Which two things must she first find out before she can fill in the table?

3 Peter is working with a program for analysing video images. He wants to get the program to draw an (x,t) graph for an accelerating car. His teacher warns him that you cannot just use any old video recording to do that: "The camera has to be stationary while the recording is being made."
What will go wrong if the camera pans to follow the car?

4 Figure 6 shows you two photographs. Both photos were taken with the shutter of the camera kept open as the player served.

a In which photo is the table-tennis player illuminated by a normal lamp? How can you see that?

b In which photo is the table-tennis player illuminated by a stroboscopic light? How can you see that?

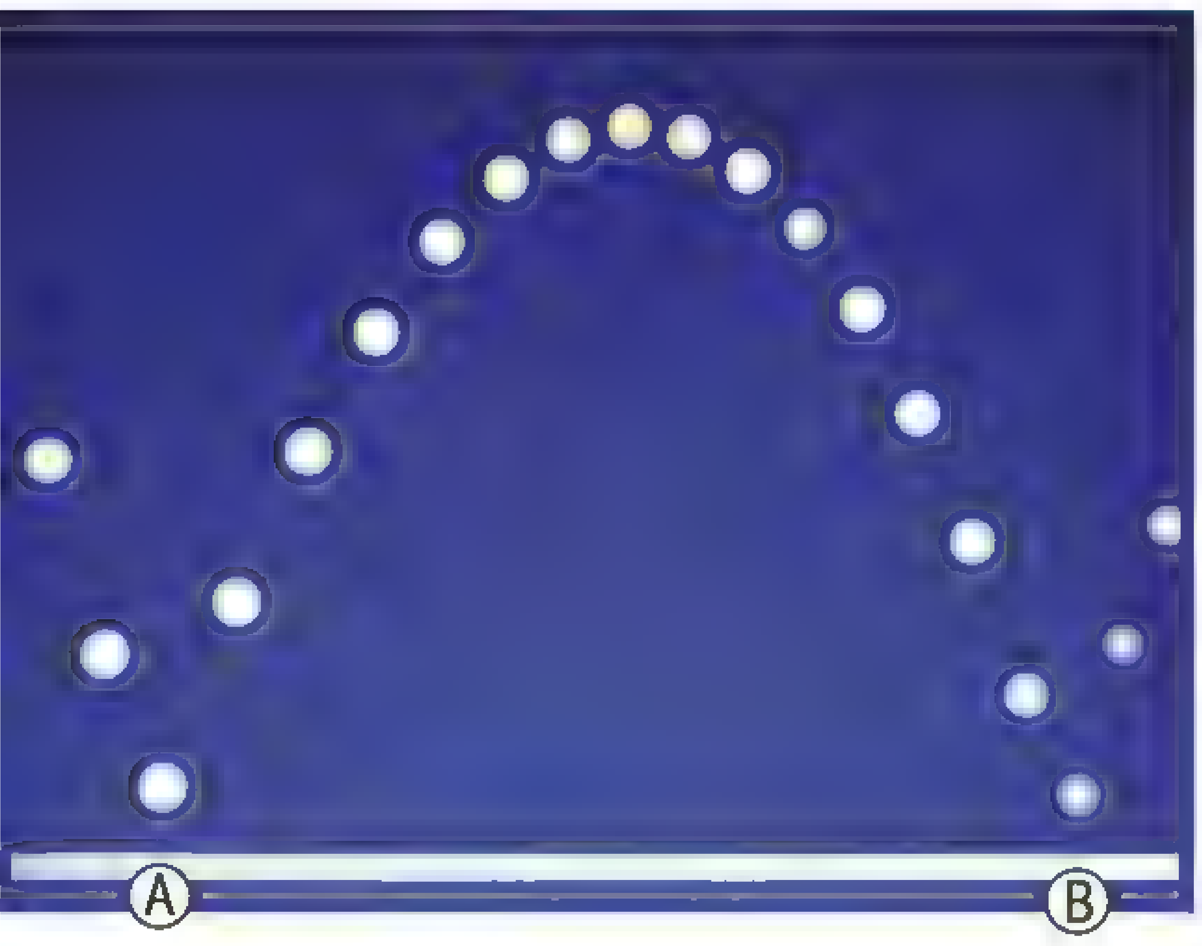
▶ figure 6
Normal light or stroboscope?

5 The photo in figure 7 was taken using a stroboscope.

a How many times did the light flash during the jump?

b The time interval between two flashes of light is 0.15 s.
How long did the entire motion take (from the first recorded moment to the last)?

▶ figure 7
the motion of a high-jumper

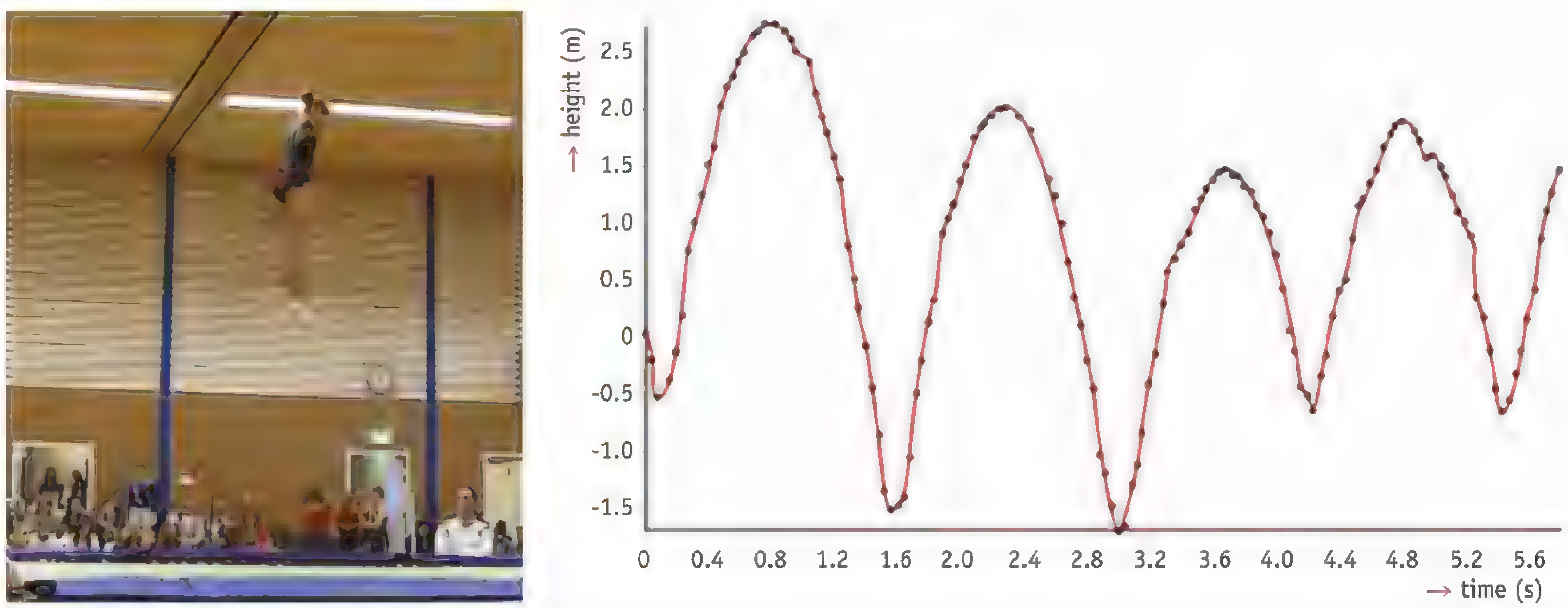


▲ figure 8
a bouncing ball

6 Figure 8 shows you a stroboscopic photo of a bouncing ball.
- **a** When is the ball moving fastest? How can you see that?
- **b** When is the ball's motion slowest? How can you see that?
- **c** The ball hits the ground at A and B. How much time is there between the two bounces? The time between two successive light flashes is 0.05 s.

7 Suppose that the photographer in figure 8 had set the stroboscope to 0.10 s.
How many times would the ball then have been photographed between A and B?

***8** Figure 9 shows you a graph made from a video recording of a person who is jumping on a trampoline. The graph plots the height against the time.
- **a** How many jumps were measured in this example?
- **b** How high was the highest jump?
- **c** At what moments was the trampolinist moving most slowly?



▲ figure 9
a video measurement of a series of jumps on a trampoline

Plus Photo finishes

9 A photo-finish picture is made using a special camera.
Copy and complete:
- **a** A screen with a ...... slit is placed in front of the camera lens.
- **b** Through this slit, a narrow strip of the ...... can be seen at the ....
- **c** If you take a single photo, you get a narrow image showing only the ....
- **d** A photo-finish picture consists of a series of ...... next to one another, all ...... in width.

*10 Figure 10 shows you the photo-finish for the men's 100 metres. The times for the athletes are given at the bottom.

a Where in the photo are the runners with the fastest times: on the left or the right?

b What is the winner's time?

c What part of the body is looked for when determining the finishing time (and therefore also when determining the winner)?

d The picture of the foot of the runner on the right-hand side of the photo is stretched out peculiarly.
Explain why.

e How much time is there between the winner and the sprinter finishing last?

f How much distance is there in the photo (in centimetres) between the winner and the sprinter finishing last?

g Calculate the time difference represented by one centimetre difference on the photo of the finish.

Place	Bib	Lane	Name	Nat	Time	Reaction
1	656	4	Bolt	JAM	9.58	0.146
2	1183	5	Gay	USA	9.71	0.144
3	665	6	Powell	JAM	9.84	0.134
4	111	3	Bailey	ANT	9.93	0.129
5	1116	8	Thompson	TRI	9.93	0.119
6	492	1	Chambers	GBR	10.00	0.123
7	1110	2	Burns	TRI	10.00	0.165
8	1215	7	Patton	USA	10.34	0.149

▲ figure 10
the finishing photo for the final of the 100 m sprint (2009 World Championships)

Nova © Uitgeverij Malmberg

2 Average speed

A cyclist who covers a stage of 184 kilometres in 4 hours has been going at an average speed of 46 kilometres per hour (km/h). Of course, this does not mean that his speed was 46 km/h the whole time. But if he had cycled constantly at 46 km/h, he would have covered the same distance (184 km) in the same time (4 hours).

Calculating the average speed

The **average speed** often gives you a good impression of how quickly something or someone is moving. You can calculate the average speed by dividing the distance travelled by the time taken:

$$\text{average speed} = \frac{\text{distance travelled}}{\text{total time}}$$

or in symbols:

$$v_{avg} = \frac{s}{t}$$

If you use a distance s in metres and a time t in seconds, you get an average speed v_{avg} in metres per second (m/s).
If you use a distance in kilometres and a time in hours, you get the average speed in kilometres per hour (km/h).

If you have a distance-time graph for a movement, you can read off the distance travelled. You make a note of where the movement started and where the motion ended. The difference between the two values is the distance travelled. A distance-time graph often starts at 0 metres. In that case, the position of the end of the motion immediately gives you the distance covered.

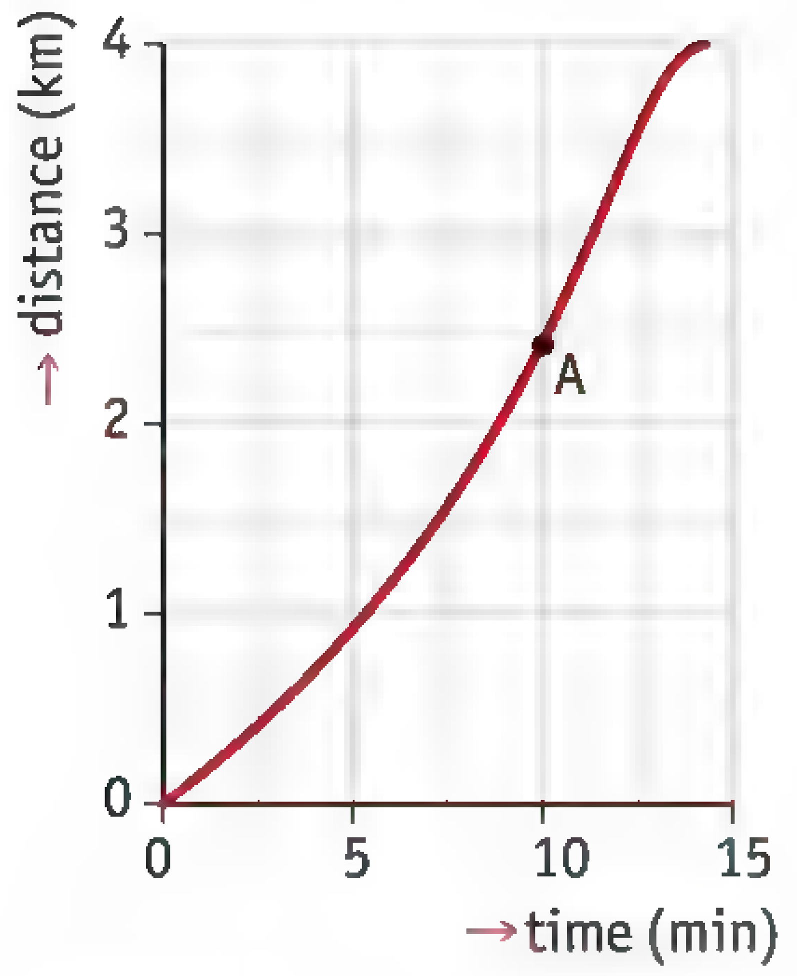
▶ figure 11
athletes at full speed in the 100 metres sprint

Worked example 1
A woman sprinter runs the hundred metres in 10.8 seconds (figure 11). Calculate her average speed.

given $s = 100$ m
$t = 10.8$ s

required $v_{avg} = ?$

working $v_{avg} = \dfrac{s}{t} = \dfrac{100}{10.8} \approx 9.3$ m/s



▲ figure 12
the (x,t) graph of a cycle ride from home to school

Worked example 2
Ben cycles to school every day. Figure 12 shows you the distance-time graph for one of his cycle rides. At point A in the graph, Ben realised that he was a bit late and started cycling faster.
Calculate Ben's average speed from point A until he got to school.

given $s = 4.0 - 2.4 = 1.6$ km $= 1600$ m
$t = 14 - 10 = 4$ min $= 240$ s

required $v_{avg} = ?$

working $v_{avg} = \dfrac{s}{t} = \dfrac{1600}{240} \approx 6.7$ m/s

Converting speeds

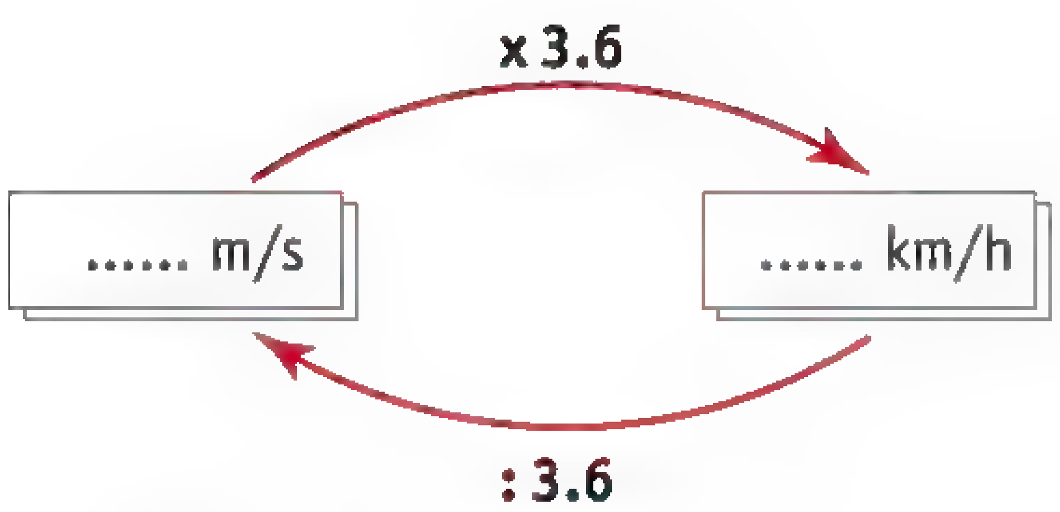
It is often useful to be able to convert speeds from m/s to km/h and vice versa. If you convert 6.7 m/s to km/h, you get a speed of 24 km/h (rounded off). That probably means more to you than 6.7 m/s, because you are used to expressing speeds in km/h.

To be able to convert the speeds, you need to know that:
1 km = 1000 m
1 h = 3600 s

For a speed of 10 m/s, the logic is as follows: If you cover 10 metres in 1 second, then (at the same speed) you would cover 3600 × 10 metres in 1 hour. So you can write:

$$10 \text{ m/s} = \frac{3600 \times 10 \text{ m}}{3600 \times 1 \text{ s}} = \frac{36{,}000 \text{ m}}{3600 \text{ s}} = \frac{36 \text{ km}}{1 \text{ h}} = 36 \text{ km/h}$$

Check that multiplying by 3.6 gives the same result (figure 13).



▲ figure 13
a flow graph for converting m/s to km/h and vice versa

Converting from km/h to m/s goes like this:

$$90 \text{ km/h} = \frac{90 \text{ km}}{1 \text{ h}} = \frac{90.000 \text{ m}}{3600 \text{ s}} = 25 \text{ m/s}$$

Check that this is the same as dividing by 3.6.

Calculating time and distance

You can use the formula:

$$v_{avg} = \frac{s}{t}$$

to work out the distance or the time as well. It is then useful to write down the formula in a different way, with the variable you want on the left.

If you know the average speed and the time, you can work out the distance travelled. You can then rewrite the formula as:

$$s = v_{avg} \cdot t$$

Nova © Uitgeverij Malmberg

If the average speed and the distance covered are known, you can calculate the time needed for the movement. In that case, you can rewrite the formula as:

$$t = \frac{s}{v_{avg}}$$

Worked example 3

A motorist knows that he can easily manage an average speed of 90 km/h for a particular route. The whole route should take him about six hours. What approximate distance is he travelling?

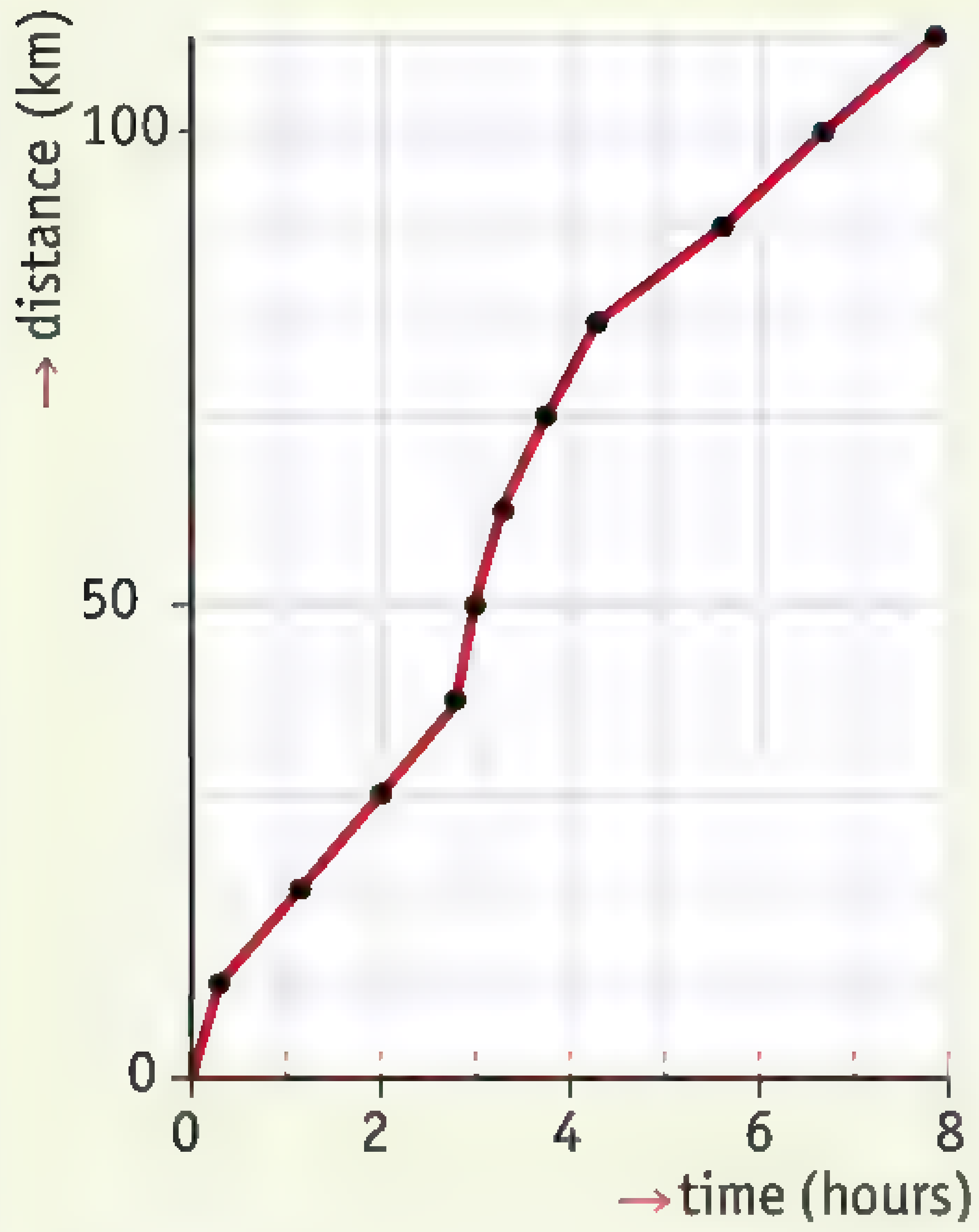
given	$v_{avg} = 90$ km/h $t = 6$ h
required	$s = ?$
working	$s = v_{avg} \cdot t = 6 \times 90 = 540$ km

Worked example 4

When Annette goes on a long hike of 50 km, her average speed (including rest stops) is about 4 km/h (figure 14).
Calculate how long the trip takes her.

given	$s = 50$ km $v_{avg} = 4$ km/h
required	$t = ?$
working	$t = \frac{s}{v_{avg}} = \frac{50}{4} = 12.5$ hours

▶ **figure 14**
Annette has nearly completed the 50 km.



▲ **figure 15**
the distance-time graph for a cycle ride through the hills

Plus Finishing time and intermediate splits

In many sporting competitions, the timers measure not only the finishing time but also a number of intermediate times, or 'splits'. These let you see how the speed varies throughout the course of the race. There is an app for smartphones that you can use to note your intermediate times, for example if you are on a cycling trip. Every time that you complete another 10 km, the split is noted.

The graph in figure 15 was made using data from that kind of app. It is the distance-time graph for a cycle trip through hilly terrain. You can use the data in the graph to work out the average speed over the whole trip. You can also work out the average speed over each 10 km section.

When you are cycling in hilly areas, your speed will not be the same all the way. You would be able to see that if the app had also registered split times for every kilometre. That would have let you calculate the average speed over each kilometre. The greater the number of splits, the more precise a picture of the changes in speed can be obtained.

Exercises

11 In road cycling competitions, the average speeds are often calculated for the winner and for the main pack (also known as the 'peloton').
- **a** What data do you need in order to be able to calculate the average speed?
- **b** What formula (in letters) can you then use to calculate the average speed?

12 You can state the average speed in m/s or in km/h.
- **a** How can you convert a speed in m/s quickly to km/h?
- **b** How can you convert a speed in km/h quickly to m/s?

13 If you know the average speed and the time, you can work out the distance travelled.
What formula do you use for that?

14 Table 2 shows the data for five movements.
Copy and complete the table, filling in the missing data.

▼ **table 2** distance, time and average speed

distance	time	average speed
45 km	45 minutes	... km/h
4.5 km	80 minutes	... m/s
200 m	... s	9.0 m/s
... km	2 hours	85 km/h
20 km	... minutes	90 km/h

15 The Richards family are going on holiday by car. The distance from their home in Drachten (in the Netherlands) to their holiday address in Confolens (in central France) is 1100 km. They leave at 04:00 in the morning and arrive at 17:00 in the afternoon.

a Calculate the average speed in km/h.

b The car is going at more than 120 km/h for most of the journey. Even so, the average speed was only 85 km/h.
What might be the reason?

16 At the athletics World Championships in 2011, the American Walter Dix ran the 100 metres in 10.08 s and the 200 metres in 19.70 s.

a Calculate the average speeds for both distances in m/s and km/h.
Show all your calculation steps.

b The average speed for the 200 metres is faster than for the 100 metres.
Give an explanation for this.

17 Luke is going on a cycling trip. Because he has a cycling computer, he knows that his average speed on a trip like this is about 18 km/h.

a Luke has planned a route through the countryside from Arnhem to Harderwijk. The route is 63 km long.
Calculate roughly how long it will take him to cover the distance.

b One day later, Luke wants to go on another trip. He does not want it to take more than six hours.
Work out the maximum distance Luke will be able to cover in those six hours.

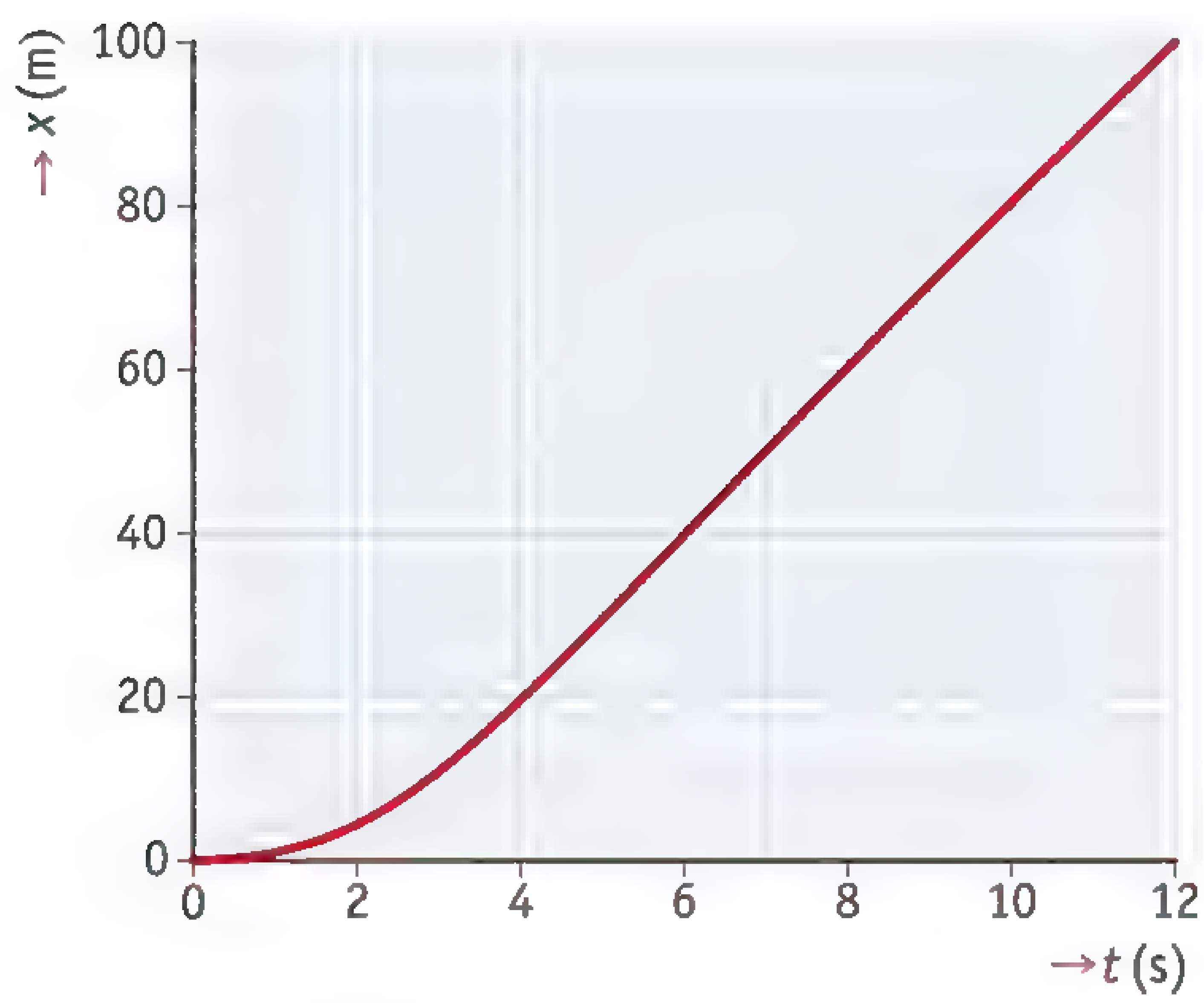
18 A triathlon competitor does the 3.8-kilometre swim in two hours, the 180-kilometre bike ride in five hours and the 42-kilometre marathon in three hours.

a Calculate the average speeds (in km/h) for each of the three disciplines individually.

b Calculate the average speed for the whole triathlon.

19 Fiona is driving towards a traffic light in a built-up area at a speed of 50 km/h. When she is 300 away from the traffic light she sees it turn green. She knows that the traffic light will stay green for 20 seconds. Work out whether she can get through the green light without breaking the speed limit of 50 km/h.

***20** Figure 16 shows you the (x,t) graph for a sprinter in the 100 m.
- **a** Calculate the sprinter's average speed in km/h.
- **b** The athlete's speed was constant for much of the time.
  Calculate that speed in km/h.



▶ figure 16
the (x,t) graph for a sprinter

***21** Jez cycles from Middelburg to Bergen op Zoom (a distance of 60 km) in three hours. He takes four hours for the return journey.
- **a** Calculate his average speed on the outward leg.
- **b** Calculate his average speed on the return leg.
- **c** Calculate his average speed over the whole journey (there and back).

Plus Finishing time and intermediate splits

22 Have a look at the data for the road cycling stage in figure 15.
- **a** What was the average speed over the entire journey?
- **b** Do the sums to work out which section was covered at a greater average speed: the first 55 km or the second 55 km.
- **c** In which section of 10 km was the average speed greatest?
- **d** The trip was over hilly terrain.
  Which part of the journey was probably uphill?

***23** Have another look at the graph in figure 15.
- **a** Calculate the greatest average speed over 10 km.
- **b** Calculate the greatest average speed over 20 km.
- **c** Explain why the answer for a is greater than for b.

Nova © Uitgeverij Malmberg

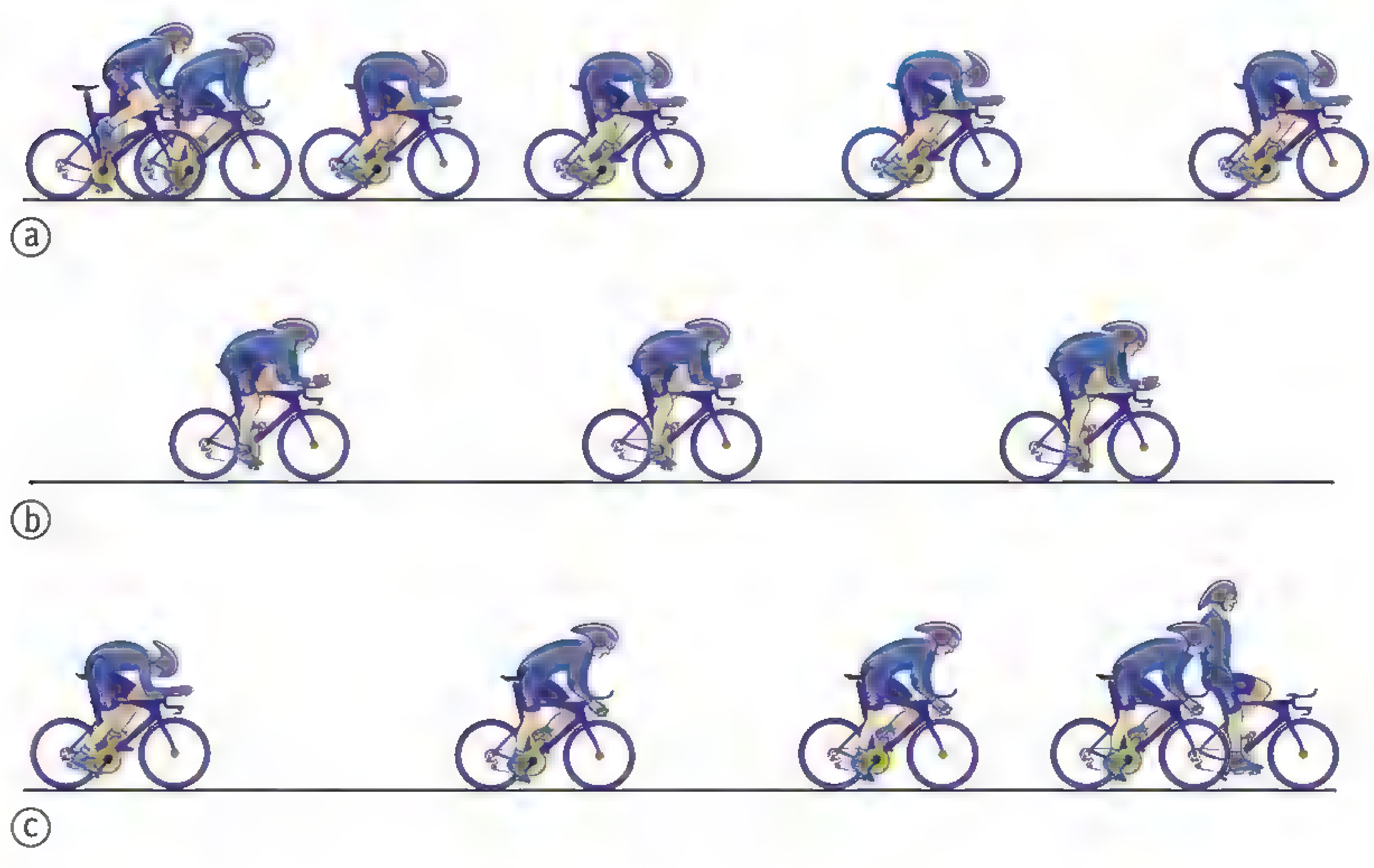
3 Acceleration – uniform motion – deceleration

Physicists categorise motion into various types. The first thing they look at is the speed; does it keep increasing, does it stay the same all the time, or does it decrease? Or, as a motorist might put it, picking up speed, driving steadily or braking. This section will teach you more about these three types of movement.

Changing speed   Experiment 3

In many sporting events, the speed changes during the event. Figure 17 gives an example: it shows stroboscopic pictures of three moments during a time trial in the Tour de France.

- In figure 17a, the cyclist is starting off. He is trying to pick up speed as quickly as possible from a stationary start. This kind of motion, in which the speed keeps increasing, is called **acceleration**.
- In figure 17b, the cyclist is going at a constant speed along a flat road. The cyclist covers the same number of metres every second. This is called **uniform motion**.
- In figure 17c, the cyclist is braking after he has passed the finishing line. His speed is therefore decreasing. A motion in which the speed keeps decreasing is known as **deceleration**.



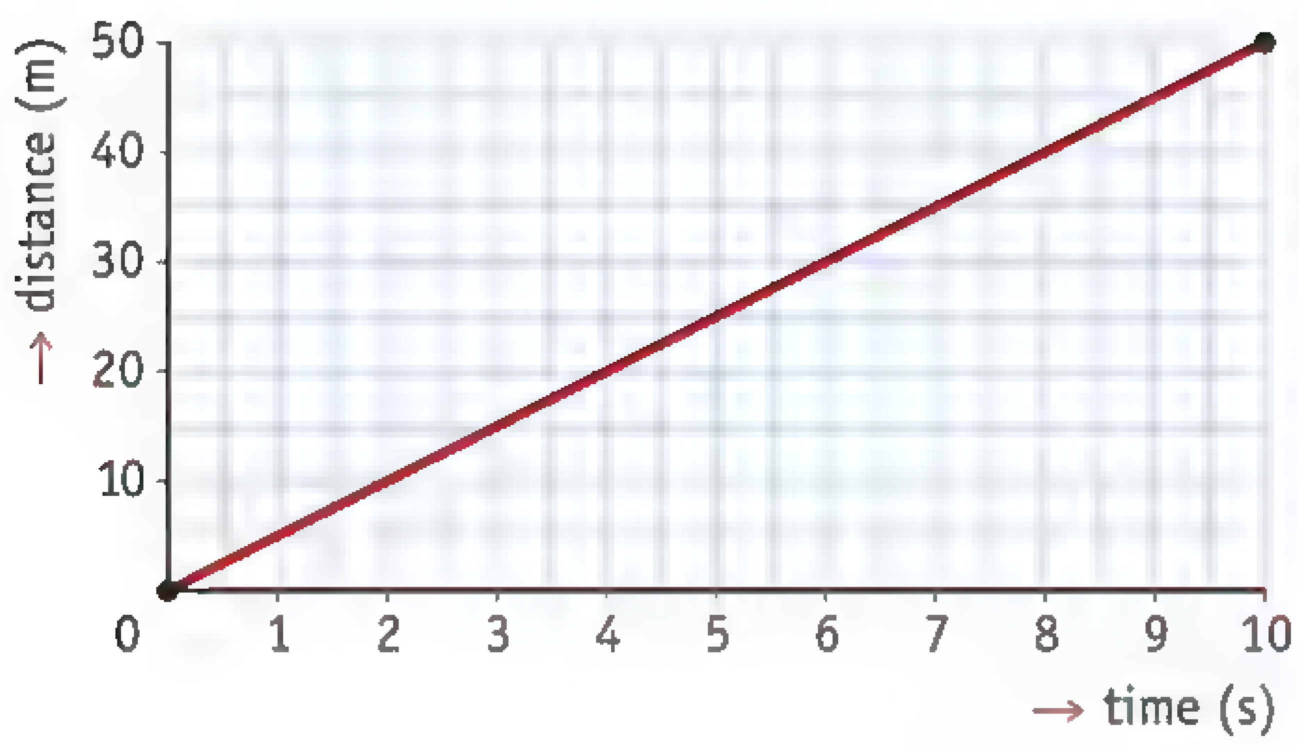
▶ figure 17
A time trial: the cyclist's motion is first acceleration, then uniform motion and then deceleration.

Uniform motion

The speed does not change during uniform motion: it is constant throughout. If you know the average speed, you immediately know what the speed was at every moment during the motion. So, for uniform motion:

$$v = v_{avg} = \frac{s}{t}$$

In this formula, v stands for the speed of the motion at any (or indeed every!) moment and t stands for the time required to cover the distance s. Figure 18 gives the (x,t) graph for a cyclist who is going at a constant speed of 5.0 m/s.



▲ figure 18
the (x,t) graph for a uniform motion

Worked example 5
Helen has made a stroboscopic photo of a toy car in uniform motion (figure 19). The time between successive flashes of light was 0.4 s. Calculate the speed of the car.

given $t = 8 \times 0.4 = 3.2$ s
$s = 82 - 2 = 80$ cm

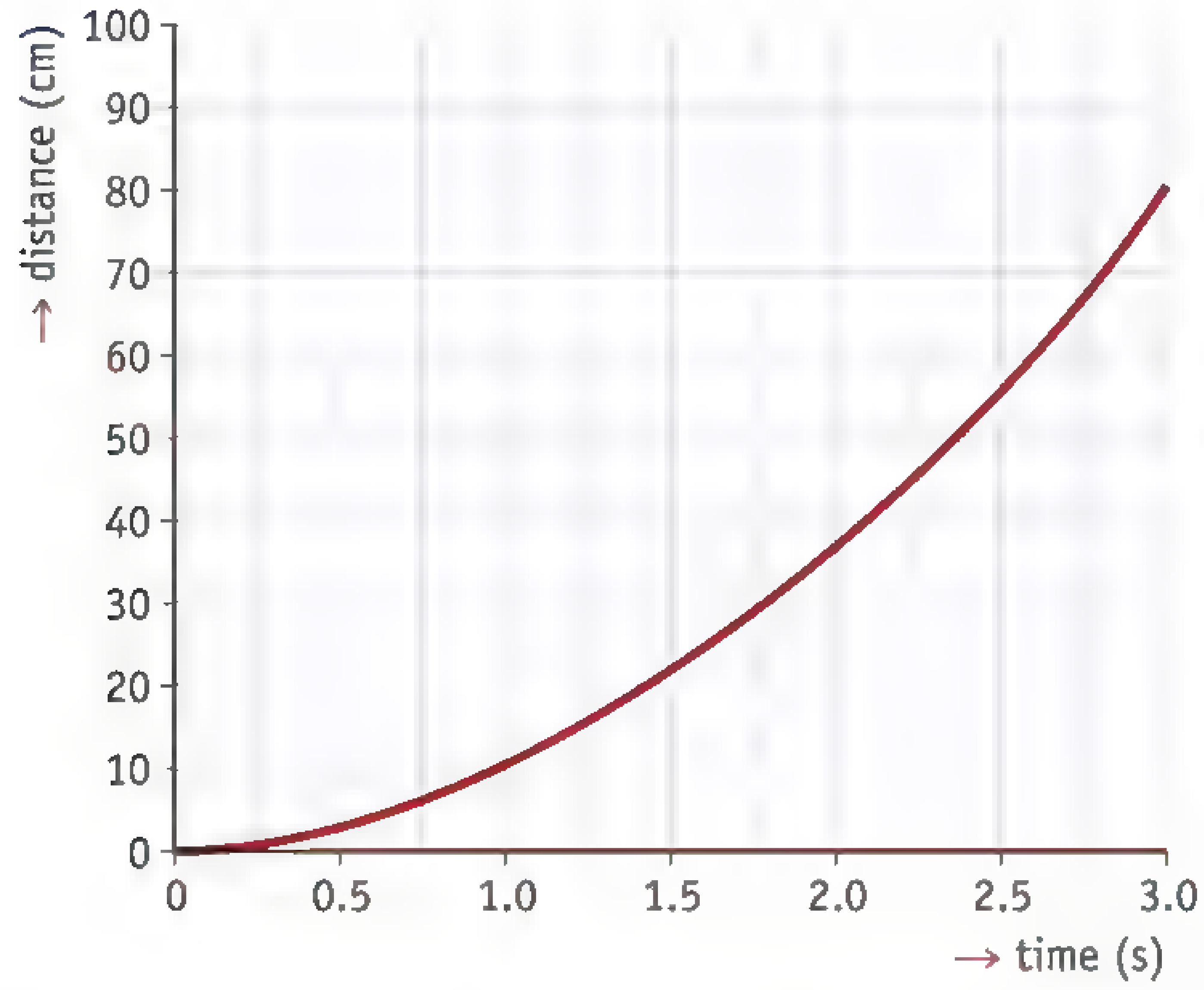
required $v = ?$

working
$$v = \frac{s}{t} = \frac{80}{3.2} = 25 \text{ cm/s}$$

▶ figure 19
a stroboscopic photograph of a toy car

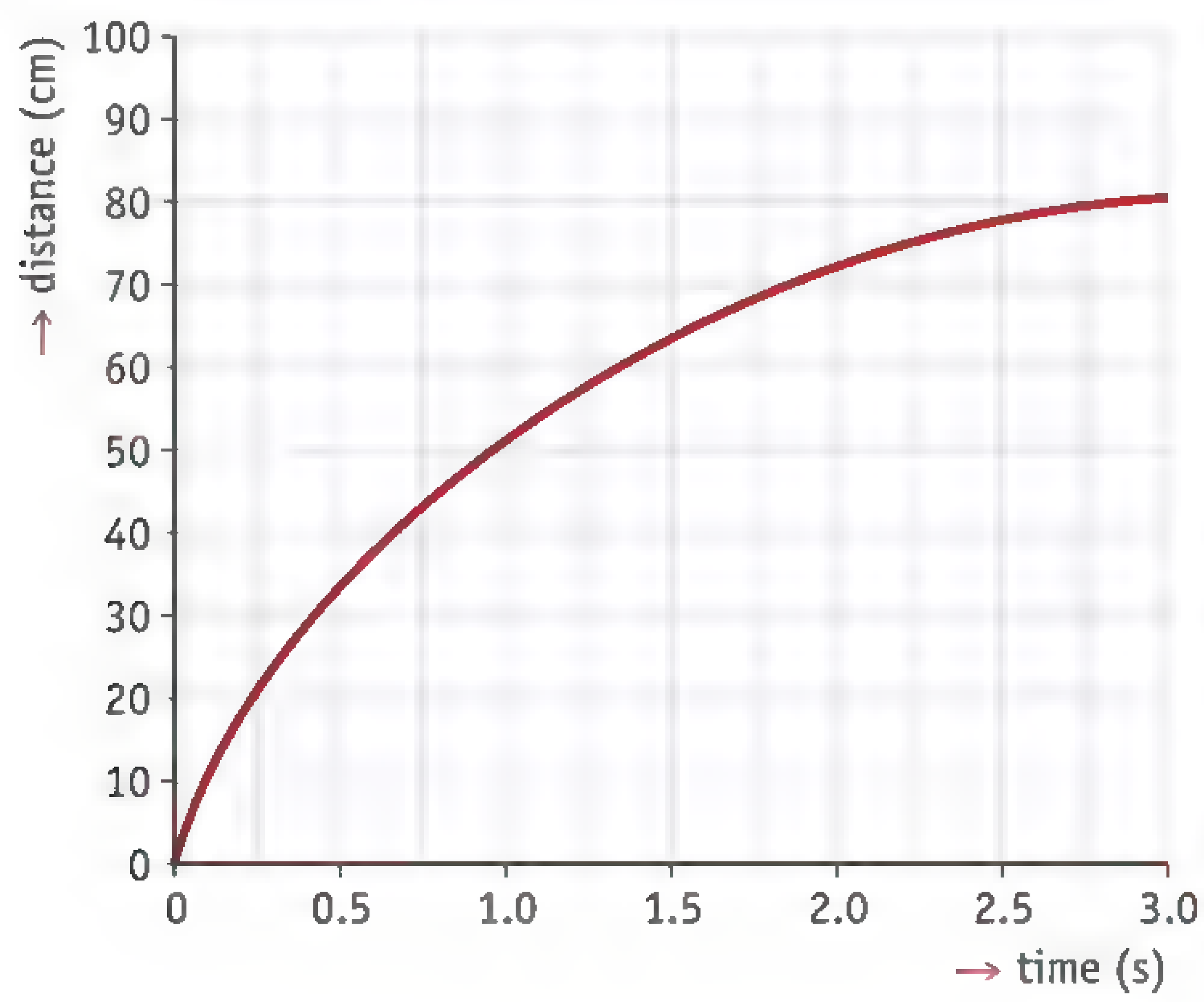
Acceleration and deceleration

If an object is accelerating it covers increasing distances in successive equal time intervals. You can see that in a stroboscopic photo of the motion: the distance between successive pictures gets greater. If you draw the (*x*,*t*) graph for this kind of motion, you get a curved line that keeps going up more steeply (figure 20).



▶ **figure 20**
the (*x*,*t*) graph for an acceleration

Figure 21 gives the (*x*,*t*) graph for a decelerating motion. In this kind of motion you see the opposite effect to an accelerating motion: the distances that the object travels in a given time keep getting less. You can also see that in the (*x*,*t*) graph the line is a curve that keeps going up more shallowly.



▶ **figure 21**
the (*x*,*t*) graph for a deceleration

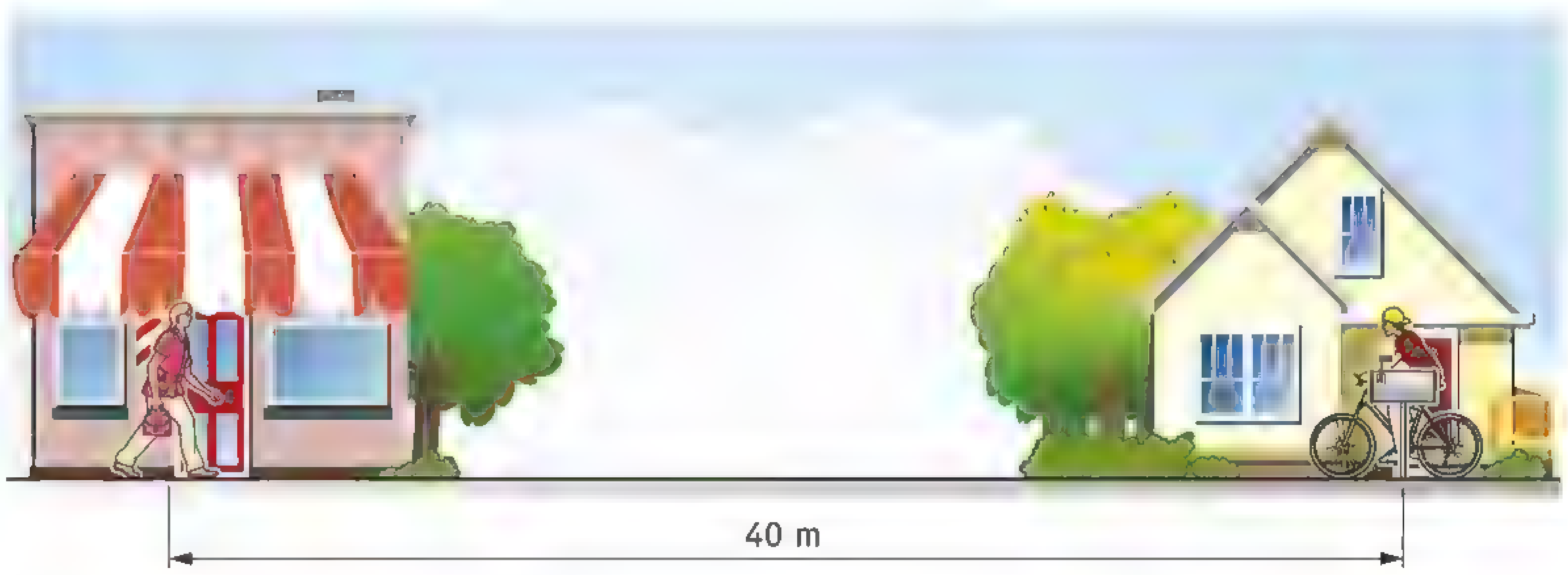
Oncoming traffic and overtaking

On most roads there is traffic in two directions. You often come across someone who is driving in the opposite direction. Every now and then you will also be overtaken by someone else. Sometimes it can be useful to record these types of motion in a single (x,t) graph. This lets you work out when and where two road users will meet.

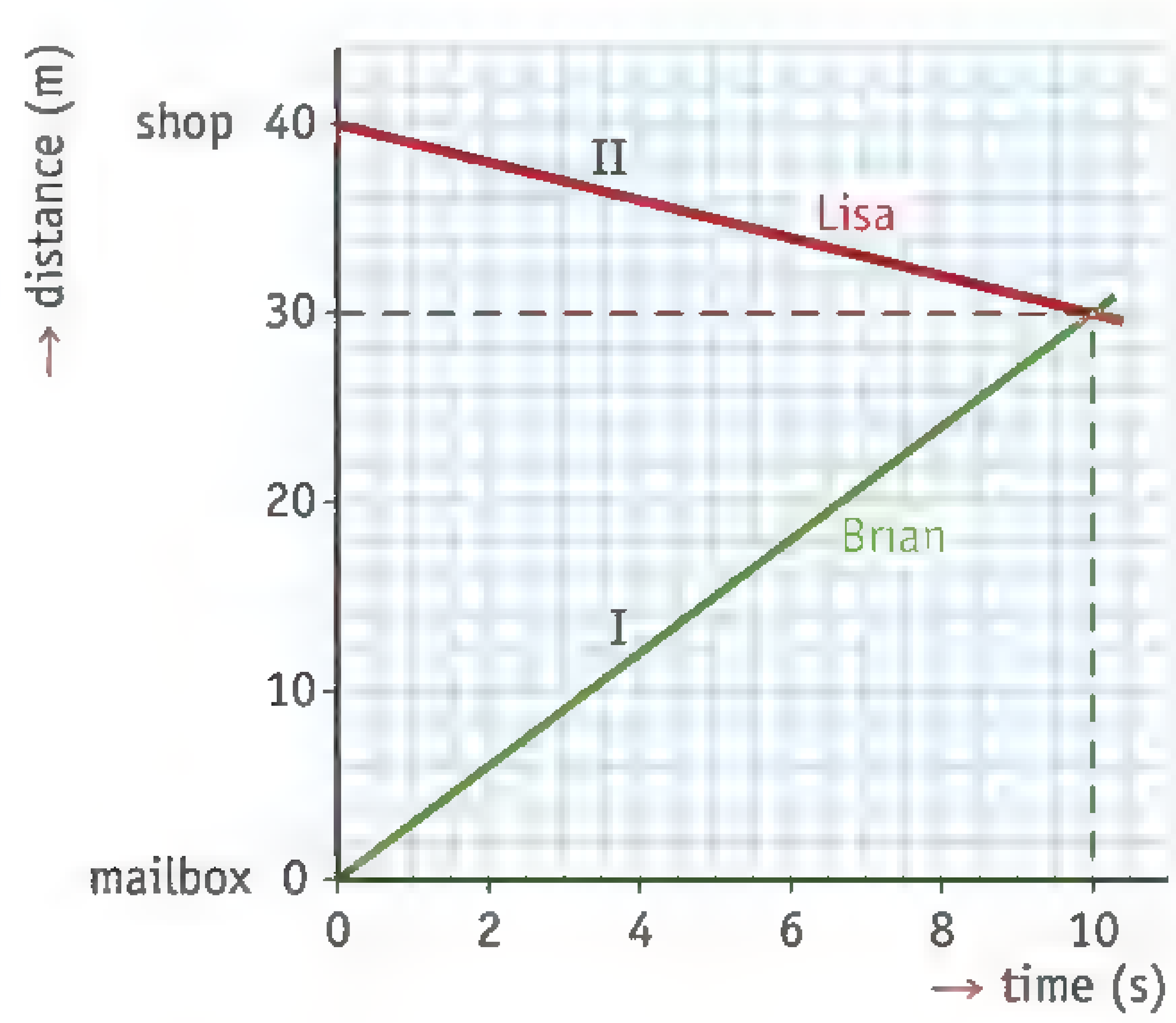
Worked example 6

Brian leaves on his bicycle at $t = 0$ s from the mailbox in front of his home, heading towards the shop 40 m further up the road. His speed is 3.0 m/s. At the same moment, Lisa leaves the shop on foot, walking towards Brian (figure 22). Her speed is 1.0 m/s.
Work out when and where they will meet.

Lisa and Brian are moving along the same path. Their motions have been drawn on the (x,t) graph in figure 23. Graph I shows Brian's motion. It starts at 0 m. Graph II shows Lisa's motion. It starts at 40 m. The coordinates of the point where the two lines intersect are $t = 10$ s and $x = 30$ m. Lisa and Brian therefore meet 30 m from the mailbox at time $t = 10$ seconds.



▶ **figure 22**
Where do Lisa and Brian meet?



▶ **figure 23**
the (x,t) graph of an encounter

Plus Navigation systems

In the past, car drivers had to use maps to find their way. Nowadays, most cars use a navigation system instead: a computer with a GPS receiver, a memory containing digital maps and a program that can quickly work out the best route to take. The program also says what the journey time will be.

This is how the navigation system calculates the journey time. First, the program works out which roads you will be travelling on. Then it works out the journey time for each section of road. Finally, the program adds up all the individual journey times. In order to calculate the journey time for a particular segment, the navigation system uses two data items: the distance that you will be travelling along that road and the expected speed on that road.

You can also find websites on the Internet that plan routes for cyclists. This type of route planner assumes the average speed of a normal cyclist as its default. You can often adjust the average speed to suit your own situation. If you are intending to use a racing bike and go quickly, you could for example set the speed to 25 km/h. If you are just going to be out for a gentle day's cycling, you could set the speed to 15 km/h.

◄ figure 24
a cyclist checking a route planner on his smartphone

Exercises

24 What is the name for a motion:
- **a** in which the speed keeps increasing?
- **b** in which the speed does not change?
- **c** in which the speed keeps decreasing?

25 Three types of motion were described in exercise 24.
- **a** Draw the (x,t) graphs for these motions.
- **b** Label each graph to show what kind of motion it is.

26 For each of the following movements, state whether it is an acceleration, uniform motion or deceleration.
- **a** The motion of your bicycle if you are moving uphill without pedalling.
- **b** The motion of a train during most of the journey.
- **c** The motion of a sprinter during the first second of the 100 metres.
- **d** The motion of a car that is braking for a pedestrian who is crossing the road.

27 A moped is leaking one drop of oil each second. Figure 25 shows a portion of the track of oil drops that it has left. The distance between points A and B is 20 m.

a How can you tell that the moped was accelerating between A and B?

b Calculate the average speed of the moped between A and B.

▶ **figure 25**
a trail of oil drips

28 Rachel is cycling to school from home. Figure 26 gives the (x,t) graph for her motion.
Which part of the graph corresponds to which of the following descriptions?

a She waits at a red traffic light.

b She cycles at a steady speed of 4.0 m/s.

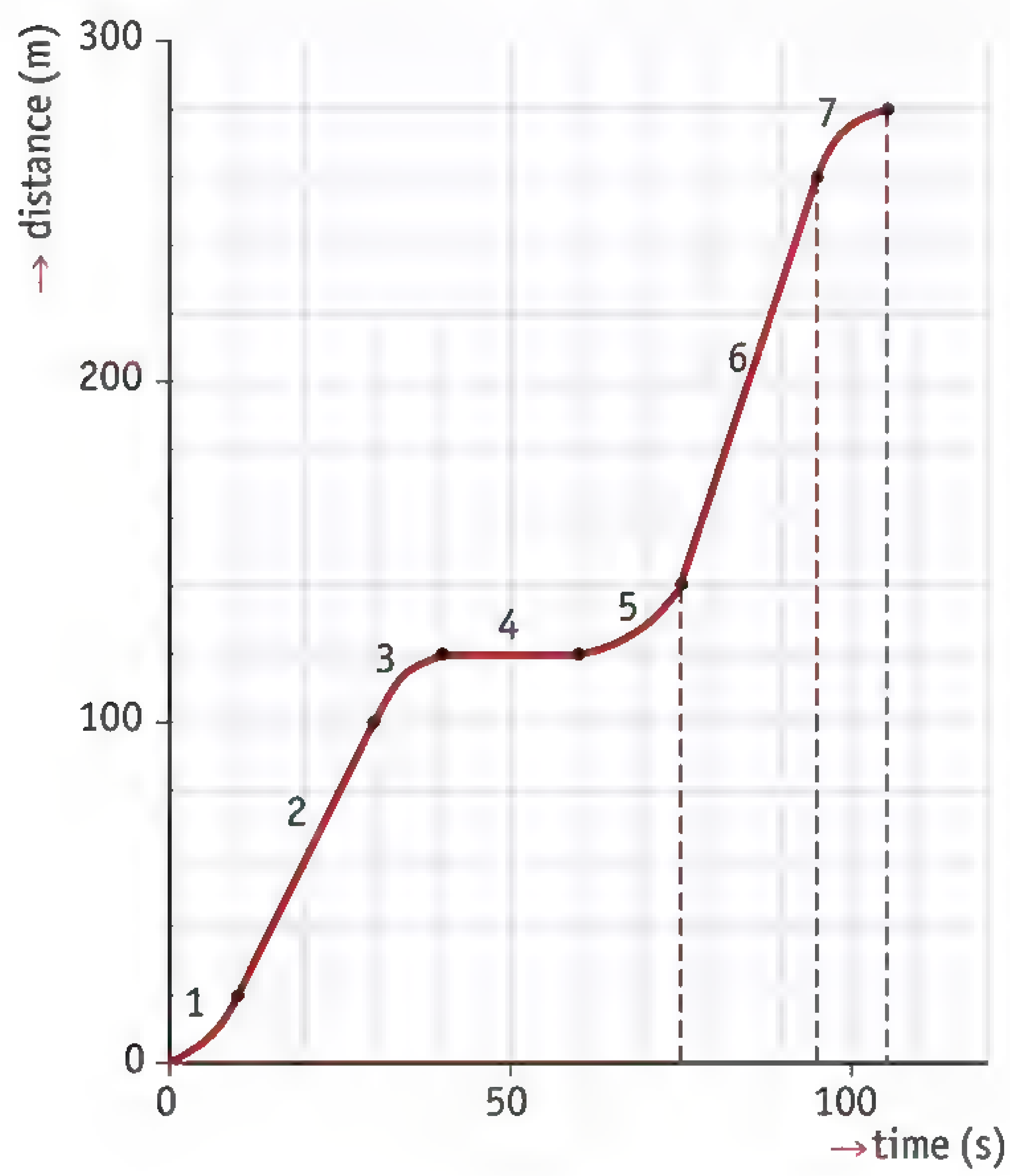
c She brakes when a traffic light goes red.

d She gets onto the bicycle and cycles off from home.

e She cycles at a steady speed of 6.0 m/s.

f She cycles off when the traffic light goes green.

g She brakes and gets off the bike when she gets to school.



▶ **figure 26**
Rachel's graph

29 Examine the (x,t) graph in figure 26 again.

a In which parts of the graph:
- is the motion an acceleration?
- is the motion uniform?
- is the motion a deceleration?

b Calculate Rachel's average speed in km/h.

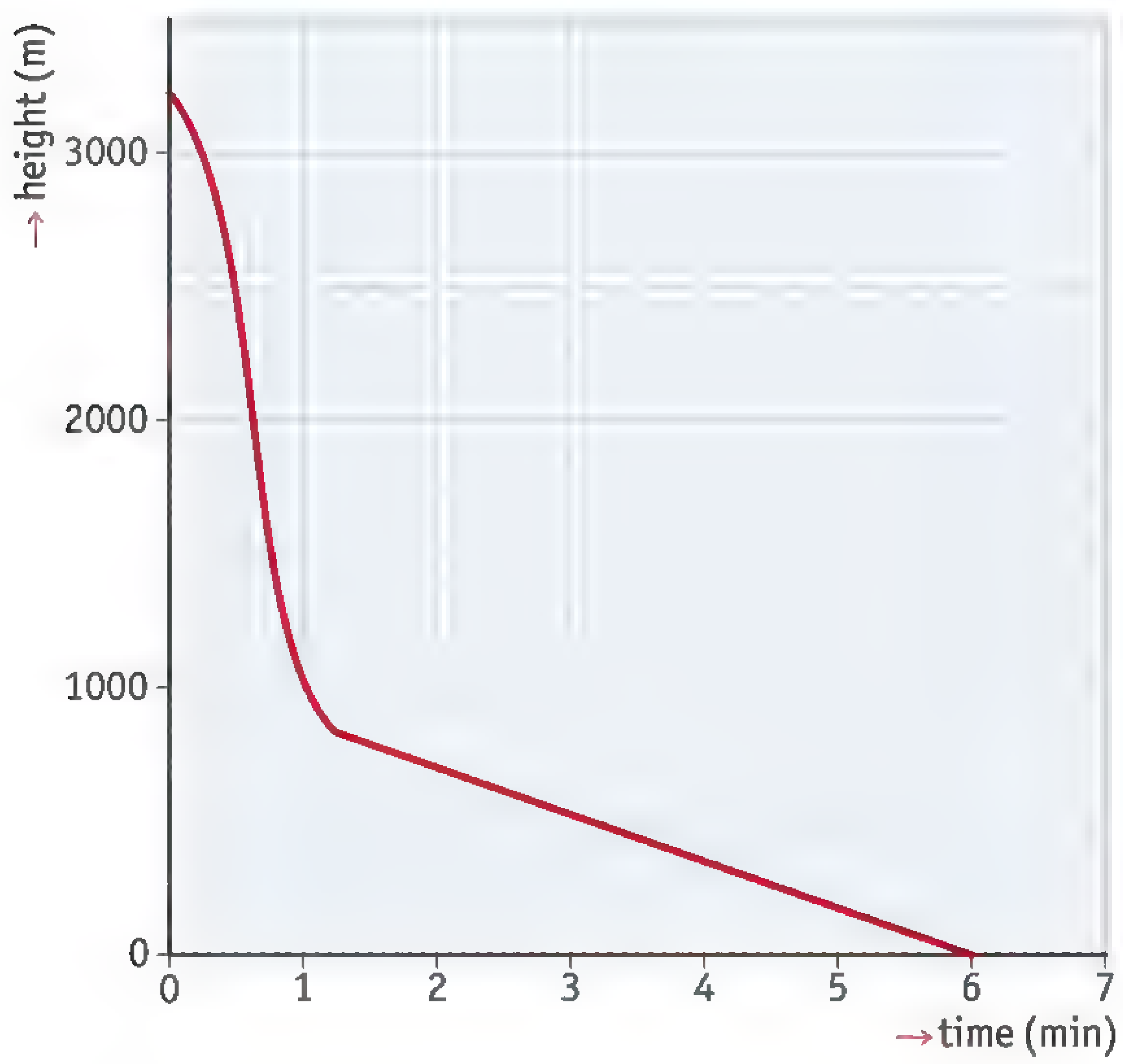
***30** Figure 27 gives the (h,t) graph for a parachute jump.

a What height did the parachutist jump from?

b At what moment did her parachute open?

c Between which points in time:
- is the motion an acceleration?
- is the motion a deceleration?
- is the motion uniform?

d Between which points in time was the parachutist moving fastest?



▶ figure 27
the (h,t) graph of a parachute jump

31 You need worksheet 6-1 for this exercise.
Kim and Amber are in the same class. Kim goes past Amber's house when she cycles to school. The worksheet shows the (x,t) graph for Kim and Amber's journey to school.

a How many metres away from Kim is Amber when she starts?

b Who cycles faster? How can you see that?

c Calculate the speeds of both pupils.

d Kim and Amber carry on at the same speeds until one overtakes the other.
Draw their motions in on the worksheet.

e Add a point marked with the letter 'P' where Kim and Amber meet up.

f After how many minutes does this happen?

***32** You need worksheet 6-2 for this exercise.
Robin and Louise are driving round on their motorbikes. Robin is waiting at the traffic lights when Louise comes along. When the lights turn green, Robin starts moving. At the same time, Louise goes past him on her motorbike. At that moment, Louise's speed is a steady 54 km/h.
- **a** Draw the graph of Louise's motion on the worksheet.
- **b** At what point in time will Louise pass Robin?
- **c** How many metres away from the traffic light is that?

Plus Navigation systems

33 Many route planners let motorists choose between the shortest route and the quickest route.
- **a** Why is the quickest route often very different from the shortest one? Explain.
- **b** A cycle route planner does not give you a choice between the shortest route and the quickest route.
  Explain why this option is not built in for cyclists.
- **c** The Google Maps site lets you determine the straight-line distance between two points. You can also get it to produce directions between those points, stating distances.
  Explain why the distance according to the directions is almost always different to the distance between the starting and finishing points 'as the crow flies'.

34 A simple route planner on the Internet uses a speed of 110 km/h for motorways and 70 km/h for other roads that are not in built-up areas.
- **a** On roads that are not motorways you are sometimes allowed to drive at 80 km/h or even 100 km/h. Why might the route planner nevertheless use 70 km/h as the average?
- **b** The Bridges family are driving from Zeewolde to Emmeloord. The overall distance is 60 km, of which 30 km is on the motorway and 30 km on ordinary roads, outside built-up areas.
  Calculate how long the Bridges will be travelling for that journey, according to the journey planner. Show all your calculation steps clearly.

Nova © Uitgeverij Malmberg

4 Braking and collisions

If you are a motorist, you must always make allowances for the traffic around you. In the event of an emergency, you have to be able to stop in time, even if the road is slippery and your vehicle is heavily loaded. Good drivers will therefore moderate their speed and keep a greater distance from the vehicle in front of them if the situation demands it.

Braking distance

When a car's brake pedal is pressed the car keeps decelerating until it comes to a standstill. During that deceleration the car will still cover a certain distance, which is known as the **braking distance**. The greater the braking distance, the higher the risk of an accident.

The braking distance depends on:

1 *The initial speed*
The **initial speed** is the speed at the moment the car begins to brake. The greater the initial speed, the greater the braking distance.

2 *The (total) mass of the car*
The greater the mass of the vehicle, the longer its braking distance will be. A fully loaded truck will have a greater braking distance than an empty one.

3 *The braking force*
The harder you press the brake pedal, the greater the braking force will be, and the shorter that will make the braking distance (as long as the car does not start to skid).

Initial speed and braking distance

Experiment 4

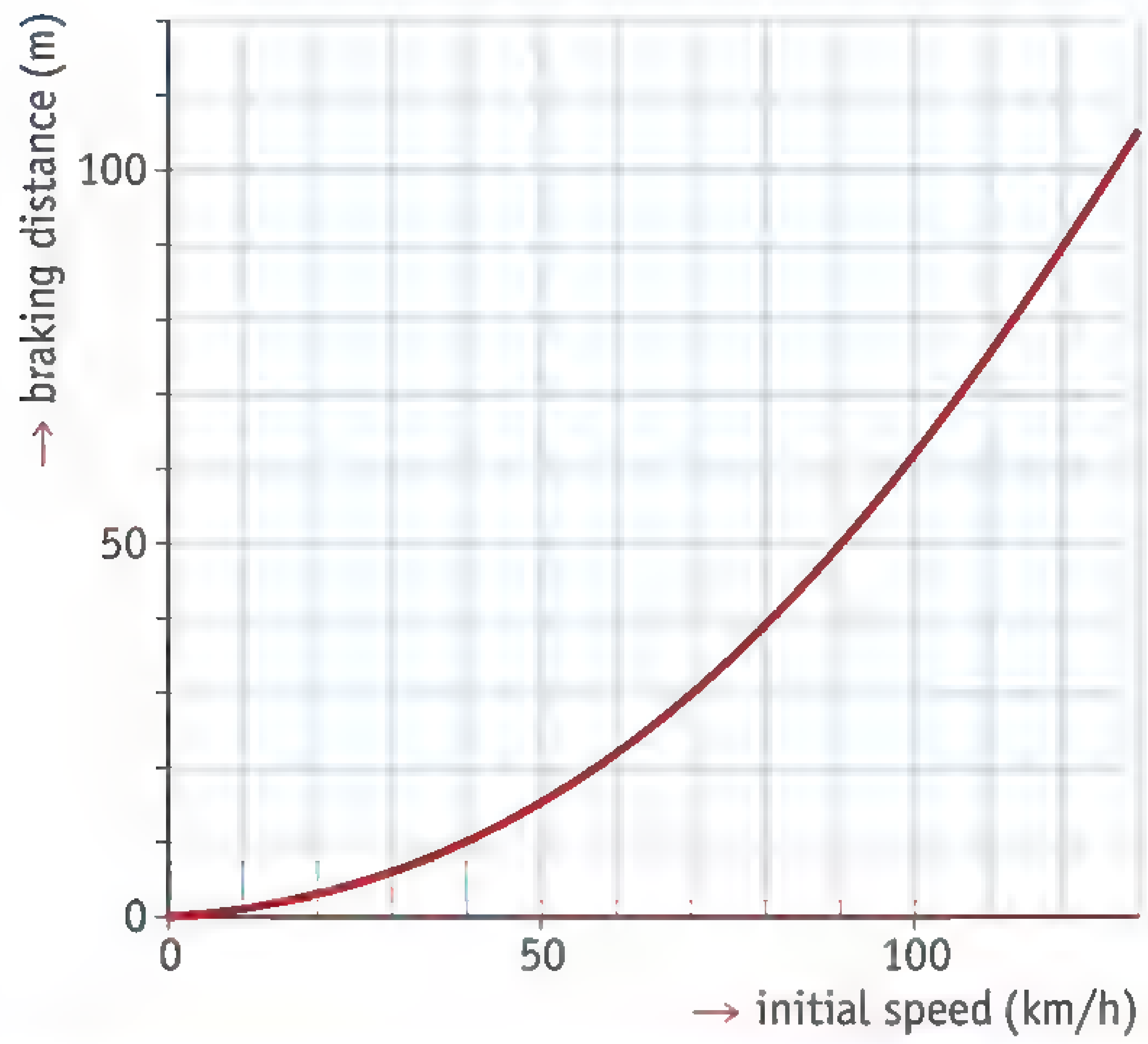
Figure 28 shows how long the braking distance is for a family car at various initial speeds. The data in the graph comes from braking tests, using the same car throughout and the same braking force. Only the initial speed was different.

The graph shows that the braking distance increases rapidly for greater initial speeds of the car. To be precise:

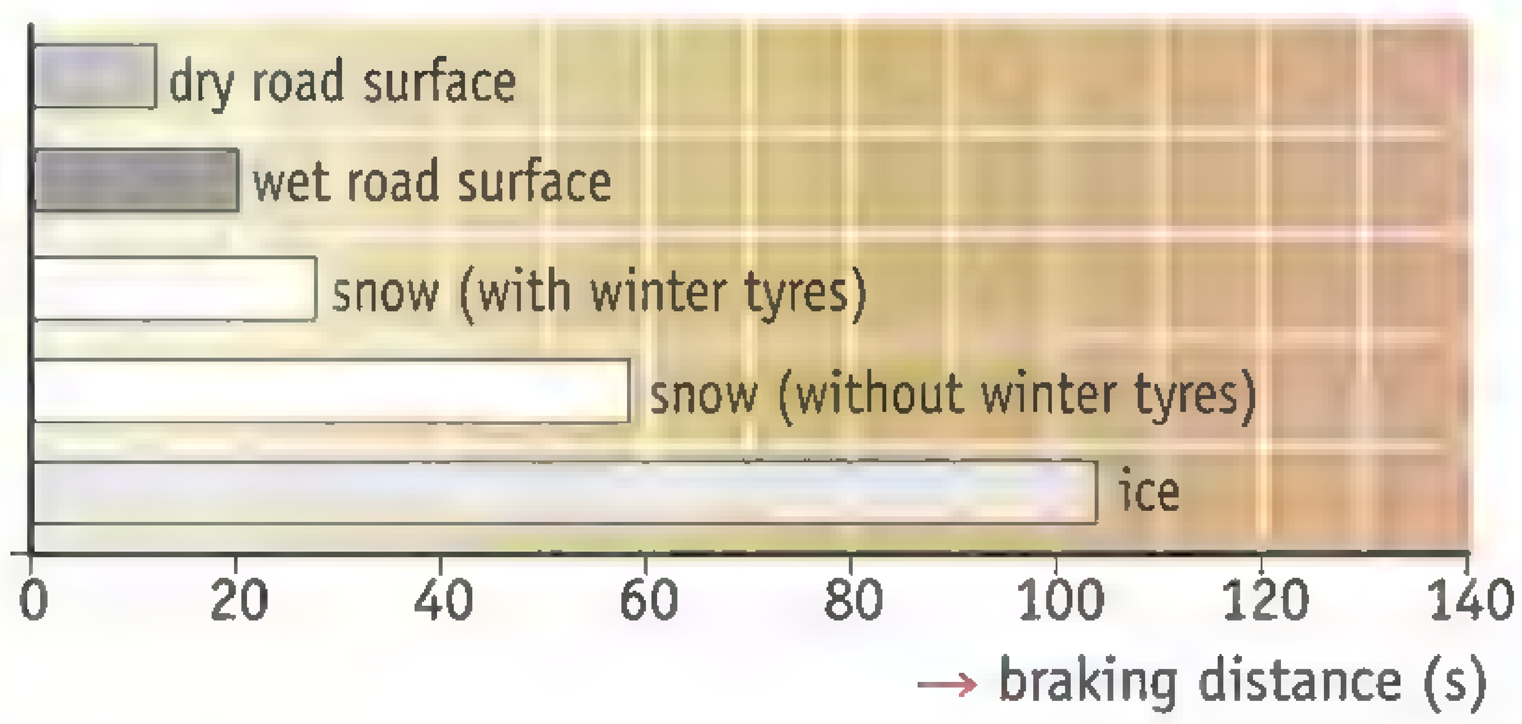
If the speed is n times greater, the braking distance becomes n^2 times longer.

If the speed doubles from 40 to 80 km/h, then the braking distance is four (2^2) times as long: it increases from 10 m at 40 km/h to 40 m at 80 km/h.

The graph in figure 28 applies for normal circumstances: brakes and tyres that are in good condition, a normal road surface and dry weather. If the brakes are worn or the road surface is slippery because of snow or ice, the braking force is less and the braking distance correspondingly longer – sometimes much longer (figure 29).



▶ **figure 28**
braking distance and initial speed



▶ **figure 29**
the braking distance of a car in various weather conditions

Worked example 7
If a car is travelling at 40 km/h, the braking distance (under normal circumstances) is 10 m.
What is the braking distance if the car is going at 120 km/h?

given $v_1 = 40$ km/h
$v_2 = 120$ km/h
$s_1 = 10$ m

required $s_2 = ?$

working v_2 is 3 × greater than v_1, so $n = 3$
s_2 is therefore $n^2 = 3^2 = 9$ × longer than s_1
The braking distance s_2 is therefore 9 × 10 = 90 m.

▲ figure 30
The mass is greater if someone is sitting on the back, and so is the braking distance.

The mass and the braking distance

The braking distance is affected by the mass as well as the (initial) speed. The more heavily a car or bicycle is loaded, the longer the braking distance will be. You will notice that, for instance, if you have someone else sitting on the back of your bike. Even if you brake just as hard as usual, it will take longer before you are stationary if there is someone sitting on the back (figure 30).

Many people go on holiday for the summer in a heavily loaded car. The braking distance of their car is then longer than they are used to. They will hopefully allow for that in their driving, for example by going more slowly, particularly when the roads are busy. This lets them shorten the braking distance, which would otherwise have become too long, back to a safe value.

You should also keep a greater distance away for the car in front on the motorway if your car is heavily loaded. If something unexpected happens, you will be less likely to drive into the vehicle in front. Maintaining a greater distance is also a good idea if it is raining or snowing. That helps reduce the chance of an accident.

Reaction time

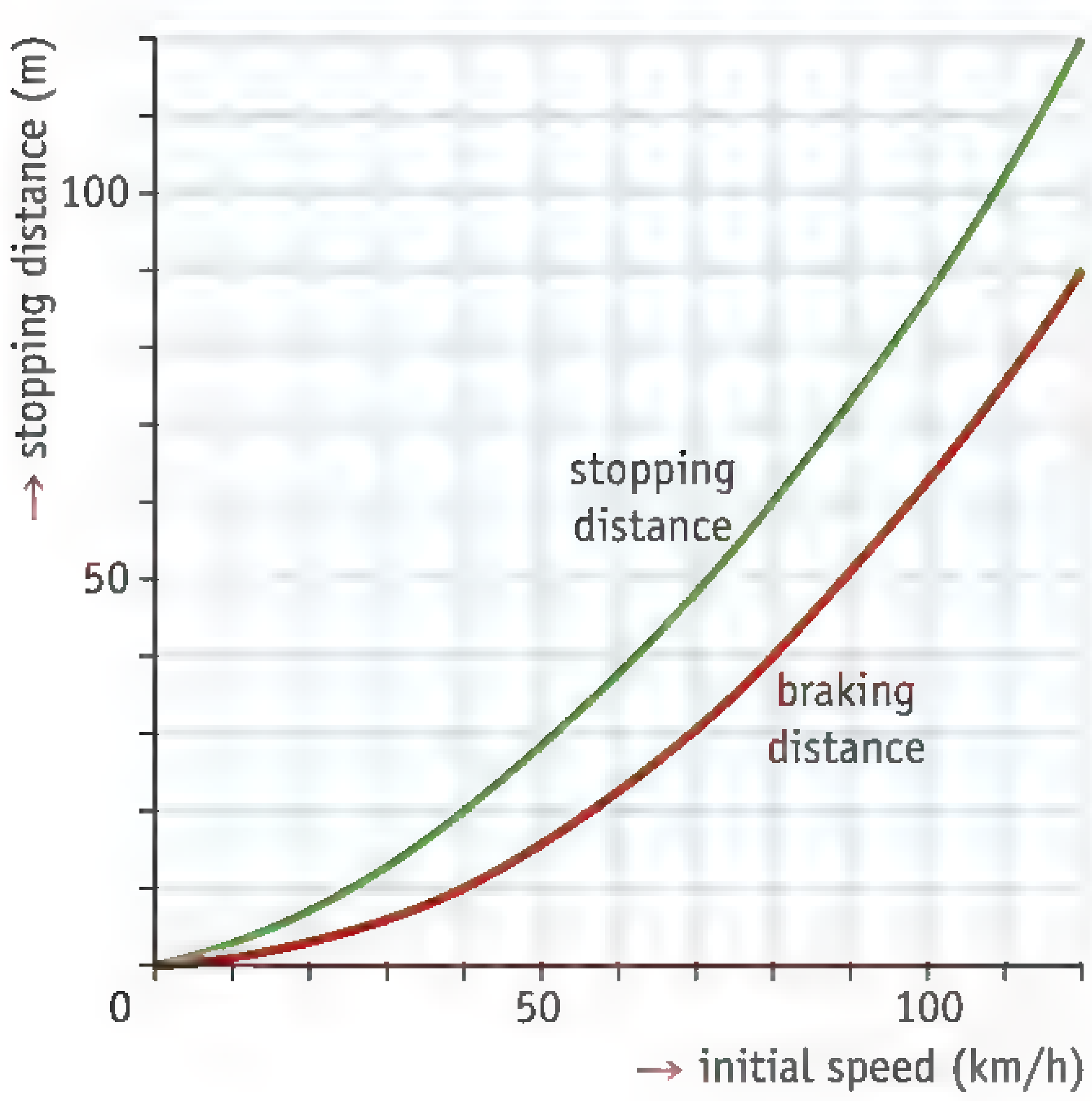
Experiment 5

If a child runs in front of a car the driver will brake. But it is impossible for the driver to react instantly: it always takes a little time before the brake pedal is pressed and the brakes are applied. The time between seeing the hazard and the brakes being applied is called the **reaction time.**

The reaction time is normally between 0.7 and 1.0 seconds. However, if you are not alert or are tired you react quite a bit more slowly. Using alcohol, drugs and some medicines also makes your reaction time longer.

The overall distance that a car needs to come to a halt – the **stopping distance** – is therefore greater than the braking distance. You also have to include the time that the car travels during the reaction time: the **reaction distance.** In other words:

stopping distance = reaction distance + braking distance



◀ figure 31
The stopping distance is greater than the braking distance.

Worked example 8
Jasmine is driving at 45 km/h along a minor road when she suddenly has to brake for a dog that runs across the road. Her reaction time is 0.8 s.
Determine the stopping distance. You can read the braking distance from figure 28.

given	for the reaction distance: v = 45 km/h = 12.5 m/s t = 0.8 s for the braking distance: According to figure 28, the braking distance is 12 m (at 45 km/h).
required	stopping distance = ?
working	reaction distance: $s = v \cdot t = 12.5 \times 0.8 = 10$ m stopping distance = reaction distance + braking distance = 10 + 12 = 22 m

▲ figure 32
The crumple zone collapses like a concertina, but the cage structure hardly deforms at all.

Plus Protection against collisions

When a car collides with something, it stops pretty much instantly. The 'braking distance' in a collision is very short and the impact experienced by the people inside is considerable. To protect the occupants, the 'braking distance' must be made as long as possible when there is a collision. There are various ways of ensuring this.

Cars are made so that the front end of the vehicle concertinas up in a collision (this part of the front is called the **crumple zone** of the car). This makes the 'braking distance' for the driver and passenger several tens of centimetres longer. The driver and passengers are safe inside the cage structure, the part of the car that is not easily deformed (figure 32).

The **safety belts** (seatbelts) make sure that the passengers decelerate at the same rate as the car. Without a seatbelt, the driver would only start decelerating when his head hit the windscreen. In addition, the seatbelts stretch a little if the car is involved in a collision. That also increases the 'braking distance' for the people inside. An **airbag** has the same function as a seatbelt, but has more 'give' in it (which means that the 'braking distance' will be a bit longer).

Exercises

35 Answer the questions below.

- **a** What three factors affect a car's braking distance?
- **b** What relationship is there between the speed of a car and its braking distance?
- **c** How does your braking distance change if you take a passenger on the back of your bike?
- **d** What factors might make someone have a slower reaction time than usual?

36 In poor conditions, a car can have a very long braking distance.

- **a** State three examples of what might create poor conditions.
- **b** In that kind of situation, the driver of the car should adapt his driving style.
  List two things that he can do to reduce the chance of accidents.

37 When a car driver sees that he has to stop, the car does not immediately start braking at that moment.

- **a** What is the term for the time between seeing the hazard and the brakes being applied?
- **b** What is the term for the distance the car travels during that time?
- **c** What is the term for the distance the car travels while braking until it is stationary?
- **d** How can you calculate the overall stopping distance?

38 A car's braking distance is greater than normal in the five situations described below.
State why for each of the situations. Choose between:
The mass is greater than normal / The braking force is less than normal.

- **a** The driver has just picked up five passengers.
- **b** The car's tyres no longer have any tread.
- **c** The road is slippery because snow has just been falling.
- **d** The brake linings are completely worn away.
- **e** The roof rack and the boot are full of luggage.

39 Many accidents occur because a car is not able to come to a halt within a given distance. Seven possible causes are listed below.

1 worn tyres
2 fatigue
3 heavy rain
4 poor brakes
5 a heavily laden vehicle
6 use of alcohol/drugs
7 excessive speed

a Which of these circumstances affect the reaction time?
b Which of these circumstances make the braking distance longer?

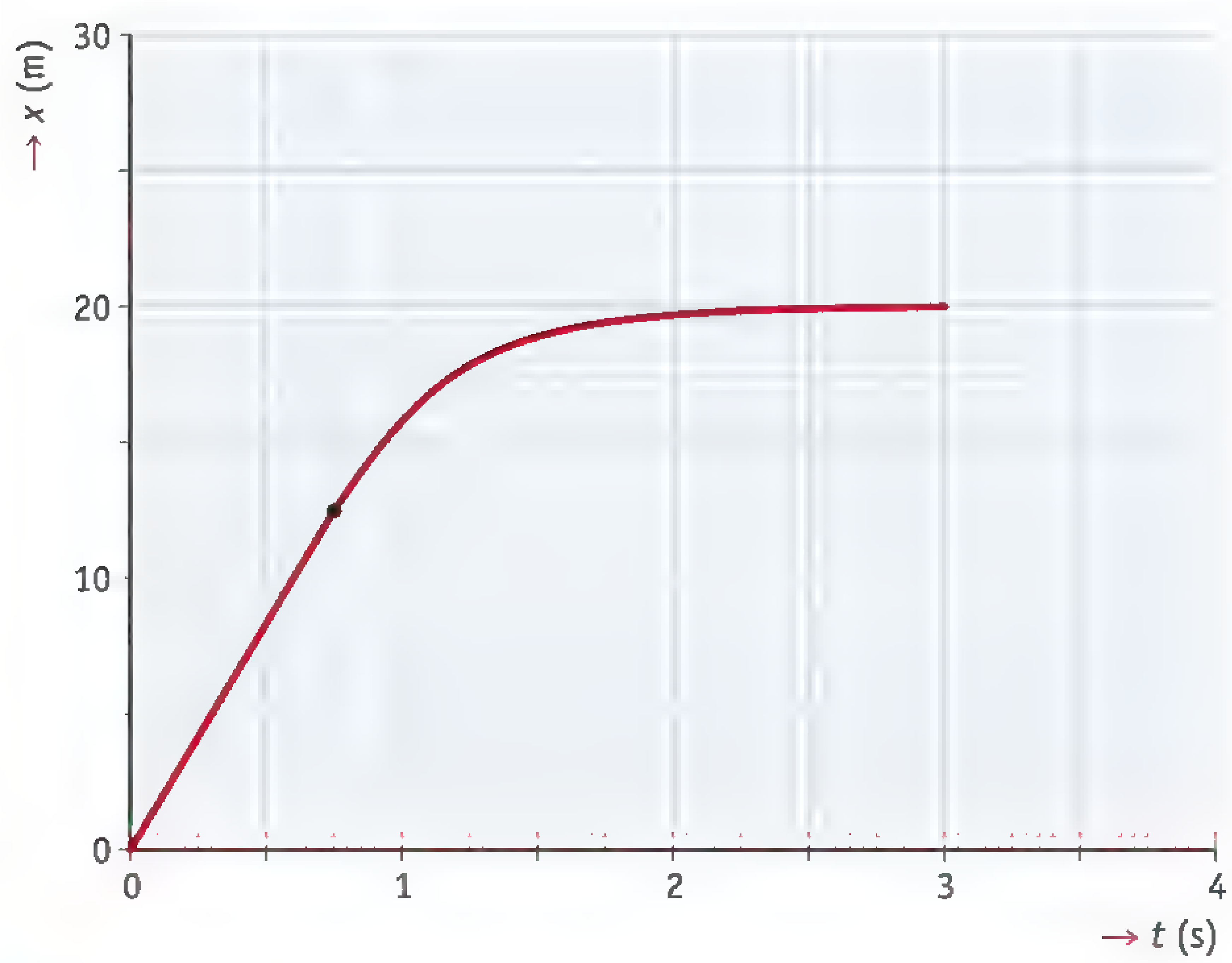
40 A family car is doing 120 km/h. The road conditions are normal.

a Read off the braking distance at this speed from figure 28.
b The driver of the car has a reaction time of 0.8 s. Calculate what his reaction distance will be at 120 km/h.
c Calculate the overall stopping distance in this situation.

41 A motorist is driving in a built-up area at 40 km/h. He suddenly sees a child crossing the road 22 m in front of his car. His reaction time is 0.9 s.
Do the calculations to show that the car and child do not quite collide. Use figure 28 to read off the braking distance.

42 Figure 33 shows the (x,t) graph for a car that has to stop suddenly when a dog crosses in front of it. The reaction time is 0.75 s.

a Use the data from figure 33 to calculate what the initial speed of the car was.
b Use the graph to help determine:
- the braking distance.
- the reaction distance.
- the stopping distance.



▶ figure 33
the (x,t) graph of a braking car

43 The national authorities recommend that car drivers on through roads should 'maintain a distance of at least 2 seconds'. See figure 34.

a Two cars are driving on the motorway at constant speed of 130 km/h, one behind the other. The second driver is sticking strictly to the 'two-second rule'.
Calculate the distance between the two cars.

b Why did the authorities choose to express the distance in seconds rather than metres?

'Stick to the two-second rule'

The national government recently started a public awareness campaign entitled 'Stick to the two-second rule'. TV commercials, billboards and an Internet site all point out the dangers of 'tailgating' and recommend maintaining a safe distance according to the so-called 'two-second rule'.

▶ **figure 34**
a news report

***44** More and more towns are introducing 30 km/h zones.

a A motorist has a reaction time of 1.0 s.
Calculate the reaction distance if a car driver is going at 30 km/h.

b The braking distance at 30 km/h is 5.3 m.
What is the stopping distance at 30 km/h?

c Calculate the stopping distance at 50 km/h. Show all your calculation steps.

d The car driver is going through a built-up area at 30 km/h when he sees a cyclist about to cross his path from the right. He has to give way to the cyclist, and is just able to stop in time.
Imagine the car driver was driving at a speed of 50 km/h. At what speed would he then have crossed the cyclist's path? Explain exactly how you got to your answer.

Plus Protection against collisions

45 Cars contain a variety of features designed to stop the occupants from being injured if there is a collision.
List three such features.

46 In a collision, the front of a car is compressed by 50 cm. In addition, the driver's seatbelt stretches sufficiently to let him move 30 cm forwards.

a What is the 'braking distance' for the occupants?

b What would have happened to the driver if he had not been wearing a seatbelt? At what point would he then have started decelerating?

Nova © Uitgeverij Malmberg

Experiments

Experiment 1 Making a stroboscopic photo 50 min

Introduction
Making a stroboscopic photo is often a good way of recording a motion. The nice thing about this kind of photo is that it summarises the whole movement in a single image. Athletes can use this kind of photograph to find out exactly how they are executing a movement. This lets them discover where improvements can be made.

Aim
In this experiment, you are going to be taking a number of stroboscopic photographs yourself.

Requirements
- stroboscope
- camera with an adjustable shutter time
- stand (tripod)
- darkened room with a dark background

Doing the experiment and writing it up
Sharing the work
Some of the class will be taking the pictures; these are the photographers. The other pupils will be taking turns to execute a movement; these are the test subjects.

Preparation
Instructions for the test subjects:
- Think up what movement you are going to carry out. Be creative and think of motions that will 'look good' on a stroboscopic photograph.
- Try out the movement. Be aware of safety, both for yourself and others.

Test runs and adjustments
Instructions for the photographers:
- Get the test subject to execute his/her movement. Determine how long the movement that is to be photographed actually takes.
- Set the height of the tripod so that the motion is neatly in the frame.
- Set the camera's shutter time so that the entire movement can be photographed.
- Set the stroboscope to a suitable rate, between 5 and 20 flashes per second.

Doing the work
Instructions for the photographers:
- Ask the person whose turn it is to get ready.
- Press the camera's shutter release and give the starting signal.
- Wait until the camera shutter has closed again.

1 View and assess the photograph.
   a Has the motion been clearly recorded?
   b Is the distance between the various images correct?
   c Was the shutter time correct – not too long or too short?

- Adjust the settings if necessary and take another photo. Otherwise, move on to the next test subject.

2 How does the photo change if the number of flashes per second is increased or decreased?
3 How does the photo change if the movement is executed more slowly?
4 How does the photo change if the shutter time is lengthened or shortened?
5 Make a distance-time graph for one of the photos you have made.

Experiment 2 Studying motions 45 min

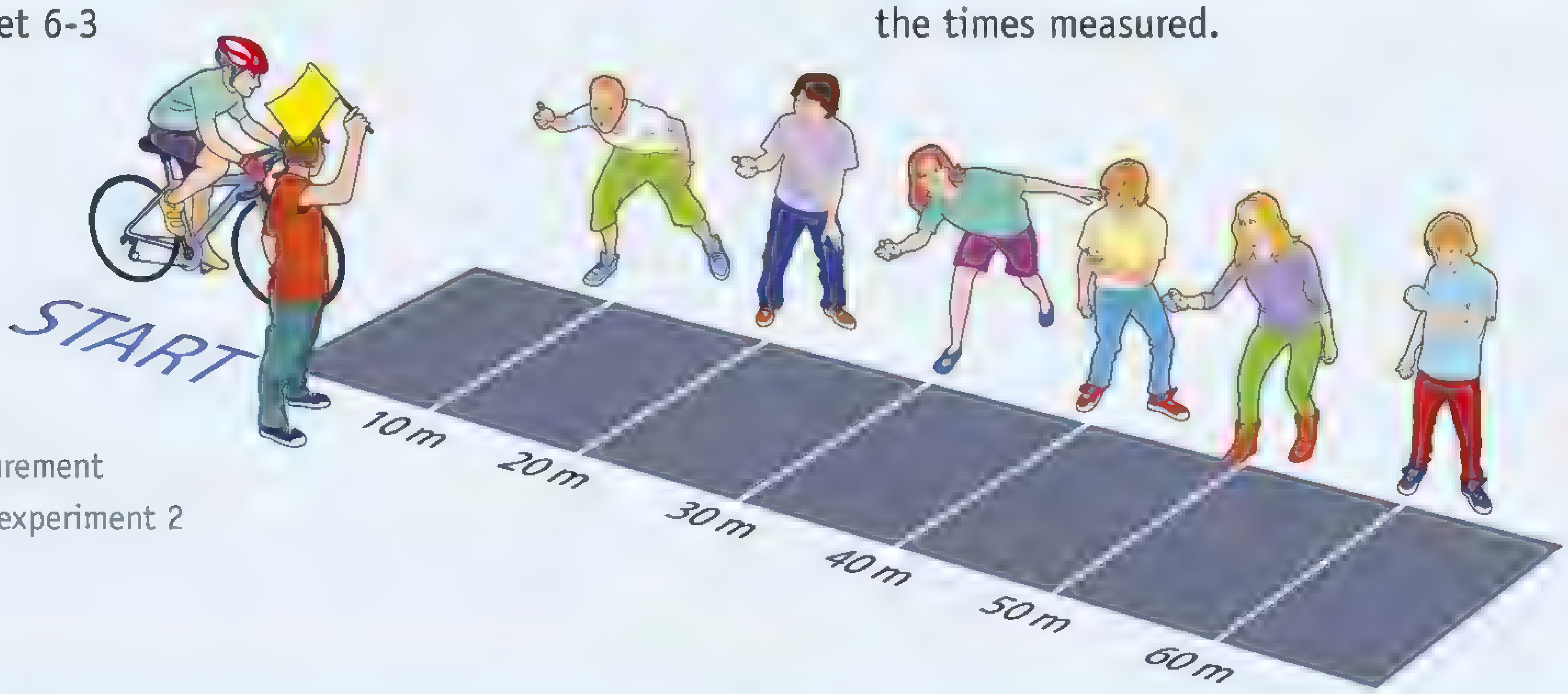
Introduction
If you want to study a motion, you start by recording it. You find out where the moving object is (its position, or the distance moved) at a number of successive moments (the time). There are then various different ways of processing the data.

Aim
You are going to determine the distances and times for five movements. You will then process that data to produce a distance-time graph.

Requirements
- six to ten stopwatches
- starting flag
- chalk
- a 10-metre length of cord
- bicycle
- worksheet 6-3

Doing the experiment and writing it up
Preparation
- A track of 60 to 100 metres should be marked out at a suitable location, with a line chalked in every 10 metres (figure 35).
- One pupil stands at the start with the starting flag. One pupil stands at each 10-metre line with a stopwatch.

Doing the work
The measurements are made as follows each time:
- The starter brings the starting flag down to start the movement. All the stopwatches are started at that same moment.
- At the point when the walker/sprinter/cyclist passes a 10-metre line, the stopwatch at that marker is stopped.
- Each pupil with a stopwatch then makes a note of the times measured.



▶ figure 35 the measurement setup for experiment 2

▼ table 3 the displacement-time table for experiment 2

	I	II	III	IV	V
displacement (m)	time (s)	time (s)	time (s)	time (s)	time (s)
0					
10					
20					
30					
40					
50					
60					
70					
80					
90					
100					

You can do this to gather data for the following five movements:
- Pupil I walks at a normal pace.
- Pupil II sprints as fast as he/she can.
- Pupil III cycles at a gentle speed.
- Pupil IV cycles as fast as possible.
- Pupil V cycles as fast as possible with a second pupil on the back.

Writing up
- All the measurements are written on the board once the experiment is complete.

1 Copy table 3 into your exercise book. Note all the measurements at the appropriate places in the table.

2 Take worksheet 6-3. Draw the distance-time graphs for each motion. Use a different colour for each.

- Answer the questions below after Section 3 has been discussed in class.

3 Compare your distance-time graphs with the distance-time graphs in Section 3.
   a For which motion (or motions) is the speed roughly constant? How can you see that?
   b For which motion (or motions) can you clearly see that there was an acceleration at the start? How can you see that?

4 Calculate the average speed for each motion, first in m/s and then in km/h.

Experiment 3 Recording motions with a ticker timer 45 min

Introduction
A ticker timer is a device that draws dots on a strip of paper known as a ticker tape. You attach the ticker tape to an object whose motion you want to record. As the motion progresses, the ticker tape is pulled through the ticker timer, which draws the dots onto the tape. You can then use the dots to determine how the object moved.

Aim
You are going to use a ticker timer to help make a distance-time graph for an accelerating motion, a uniform motion and a decelerating motion.

Requirements
- ticker timer
- power supply box
- wires
- pressure switch
- three 60-centimetre lengths of ticker tape
- ruler
- worksheet 6-4

Doing the experiment and writing it up
Preparation
- You will be doing this experiment in pairs.
- Plug the ticker timer in so that it is connected to the power supply box. Your teacher will tell you the correct alternating voltage to use.
- Place a 60 cm strip of ticker tape in the ticker timer.

Doing the work

Measurement 1 An acceleration
- Pupil 1 gives the starting signal and switches the ticker timer on at the same time.
- Pupil 2 pulls the strip through the ticker timer at a steadily increasing speed.
  Note: the whole movement has to be recorded on the tape.
- Label the strip 'Acceleration'.
  Place an S (for start) by the first dot on the strip.
  Place an F (for finish) by the last dot on the strip.

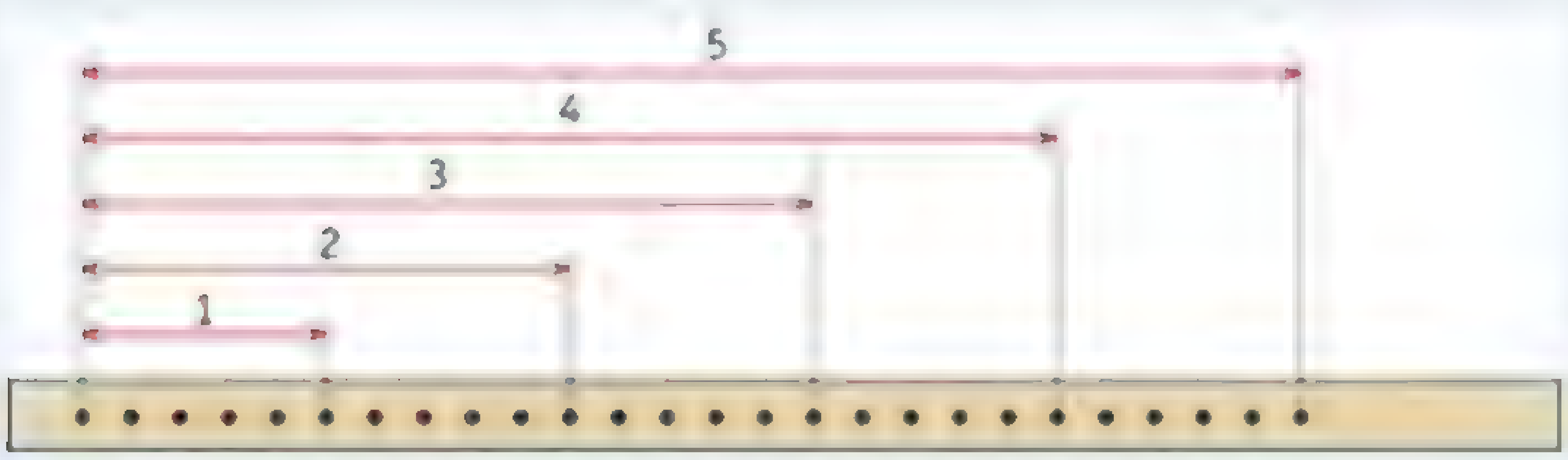
Measurement 2 Uniform motion
- Place the second strip of ticker tape in the ticker timer.
- Pupil 1 gives the starting signal and switches the ticker timer on at the same time.
- Pupil 2 pulls the strip through the ticker timer at a steady speed.
- Label the strip 'Uniform motion'.
  Place an S next to the first dot on the strip.
  Place an F next to the last dot on the strip.

Measurement 3 A deceleration

- Place the third strip of ticker tape in the ticker timer.
- Pupil 2 starts by pulling the strip through the ticker timer at a substantial speed.
- Pupil 1 then immediately gives the starting signal and switches the ticker timer on at the same time.
- From that moment on, pupil 2 pulls the strip further through the ticker timer at a steadily decreasing speed. (Practice this a couple of times without turning the ticker timer on before actually doing the experiment.)
- Label the strip 'Deceleration'.
  Place an S next to the first dot on the strip.
  Place an F next to the last dot on the strip.

Writing up

- Use a pencil and ruler to draw a line across the tape through the first dot.
- Count five dots further and place another line. Keep doing this until you get to the end of the tape (see figure 36).
- Process the other two tapes in the same way.



▲ **figure 36**
how to place the lines on the ticker tape

1 Copy table 4 into your exercise book.
Measure the distances travelled as shown in figure 36.
Note the distances in the correct place in the table.

2 Make a note of the time taken to travel each distance in the second column of the table. Some ticker timers make fifty dots a second; others make a hundred dots a second. Your teacher will give you the details for your ticker timer.

3 Take worksheet 6-4. Draw a distance-time graph:
a of an acceleration.
b of a uniform motion.
c of a deceleration.

4 What does the graph look like for:
a an acceleration?
b uniform motion?
c a deceleration?

5 Calculate the average speeds of the movements that were recorded on the ticker tape. Always show all your calculation steps.

▼ **table 4** the measurement results for experiment 3

		measurement 1	measurement 2	measurement 3
distance number	time (s)	distance (cm)	distance (cm)	distance (cm)
0	0	0	0	0
1				
2				
3				
4				
5				
etc.				

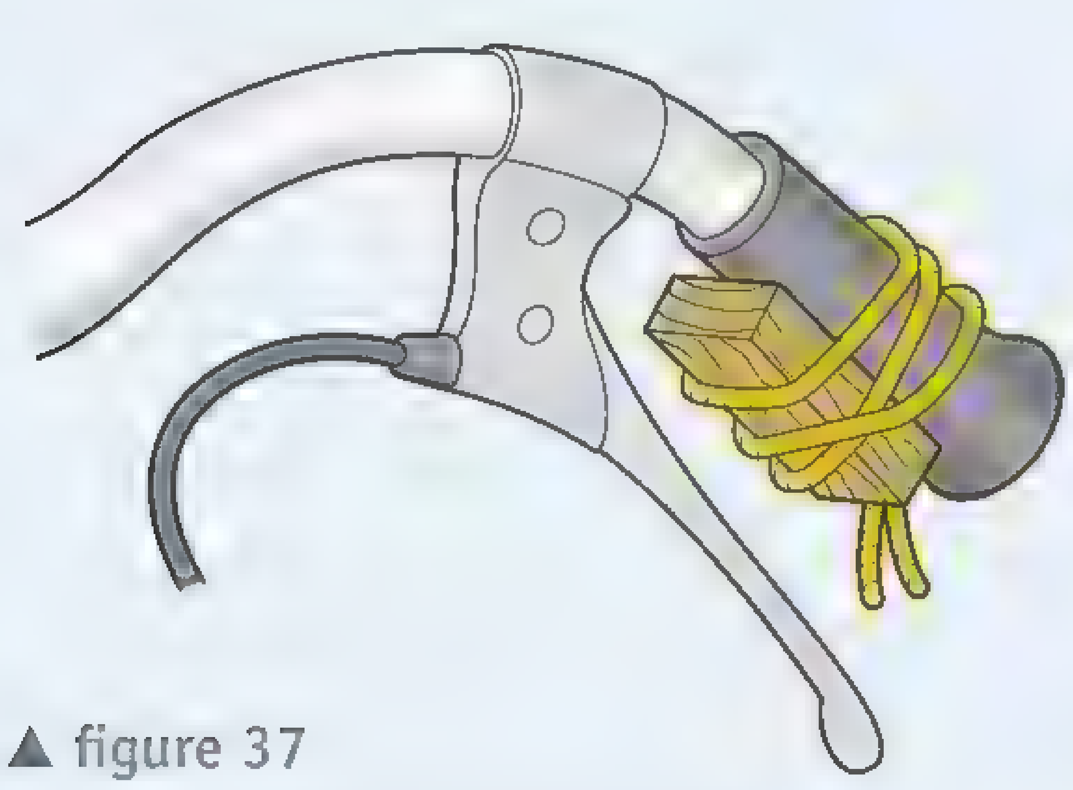
Experiment 4 The braking distance of your bicycle 45 min

Introduction
When you brake on your bicycle, you do not come to a halt immediately. You still travel a certain distance further during braking. This distance is known as the braking distance.

Aim
You will be investigating the braking distance for a bicycle. The question you are studying is:
How does the braking distance of your bicycle depend on the initial speed (the speed at the moment you begin to brake)?

Requirements
- stopwatch
- measuring tape
- bicycle (with hand-operated brakes)
- two wooden blocks
- cord
- worksheet 6-5

Doing the experiment and writing it up
Preparation
- You do this experiment in pairs: pupil 1 cycles, pupil 2 records the time and measures the braking distance.
- Fix the wooden blocks to your handlebars as shown in figure 37. This will make sure you can brake using the same braking force each time.



▲ figure 37
This lets you brake with the same braking force each time.

- Mark out a distance of 10 m on the school playground or a quiet road.

Doing the work
- Pupil 1 cycles at a constant speed through the 10-metre section. After passing the line at 10 m, he/she immediately brakes until coming to a halt.
- Pupil 2 measures the time that pupil 1 took to cover the 10 m. After the bicycle stops, he/she measures how long the braking distance was.
- Carry out the measurements stated above for five different speeds (ranging from very slow to as fast as possible).

1 Copy table 5 into your exercise book.
Note all the measurements down in the table: the times in the first column and the braking distances in the third column.

Processing

2 Calculate the speed before braking for each measurement. Make a note of the speed in the second column of the table.

3 Take worksheet 6-5. Make a graph of your observations in which you plot the braking distance against the initial speed (with the braking distance on the vertical axis and the initial speed on the horizontal axis).

▼ **table 5** the measurement results for experiment 4

10-metre time (s)	speed before braking (m/s)	braking distance (m)
-	0	0

Experiment 5 Reaction time 15 min

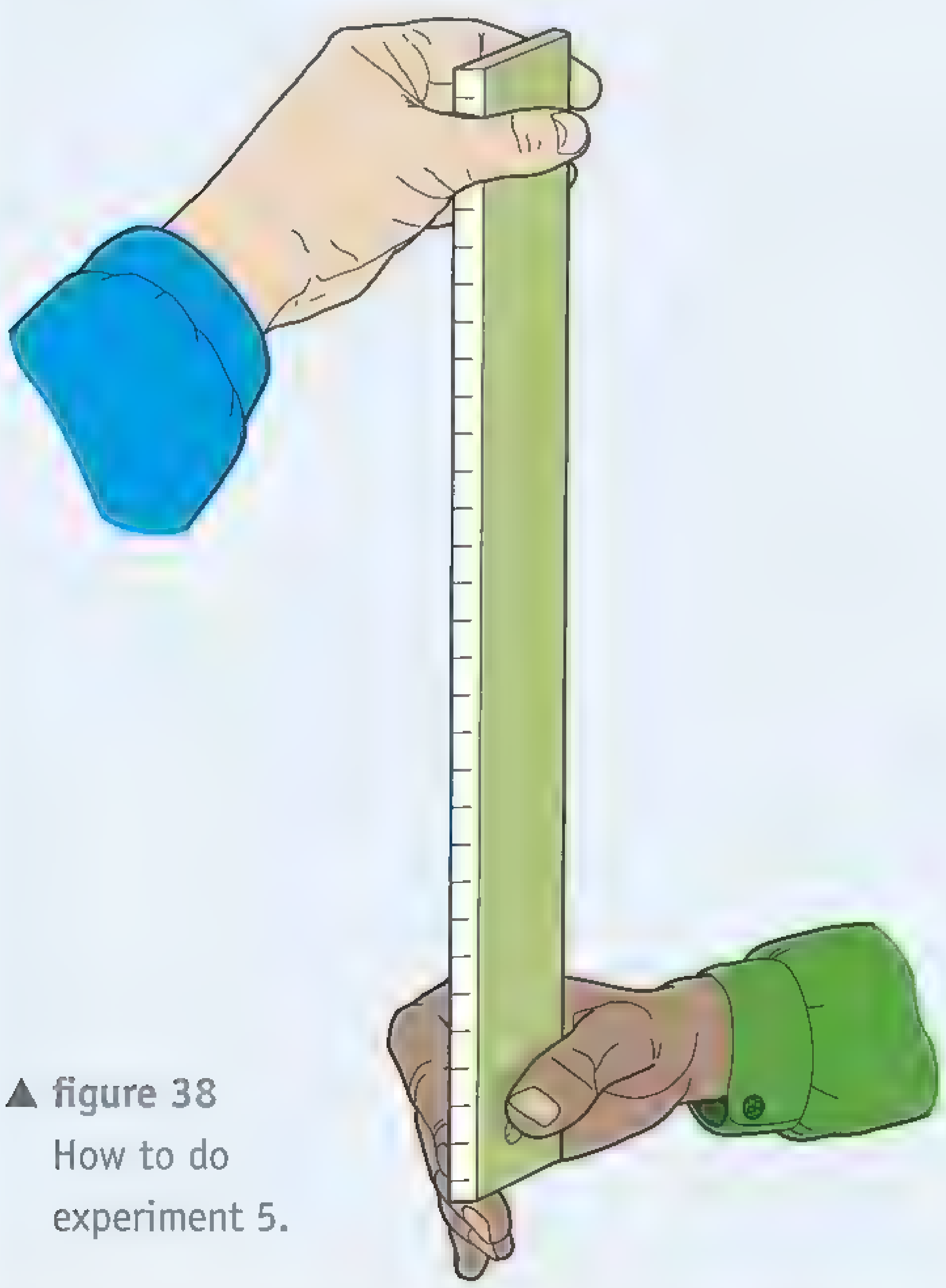
Introduction
You've probably had it happen to you: you're cycling along a busy street and all of a sudden someone comes out onto the road in front of you. It makes you jump and you brake sharply. But no matter how quick your reactions are, it always takes a moment before you apply the brake. The time between seeing and responding is known as the reaction time.

Aim
In this test, you are going to determine your own reaction time.

Requirements
- a 30 cm ruler

Doing the experiment and writing it up
Sharing the work
You do this experiment in pairs. Pupil 1 is the test subject; pupil 2 is the tester. Half way through the experiment, you swap roles.

Doing the work
- Pupil 2 holds the ruler at the top by the 30 cm mark. Pupil 1 holds a thumb and forefinger at the zero mark. See figure 38.



▲ figure 38
How to do experiment 5.

- Pupil 2 lets go of the ruler with no warning. The test subject tries to grab the ruler between thumb and forefinger as quickly as possible.

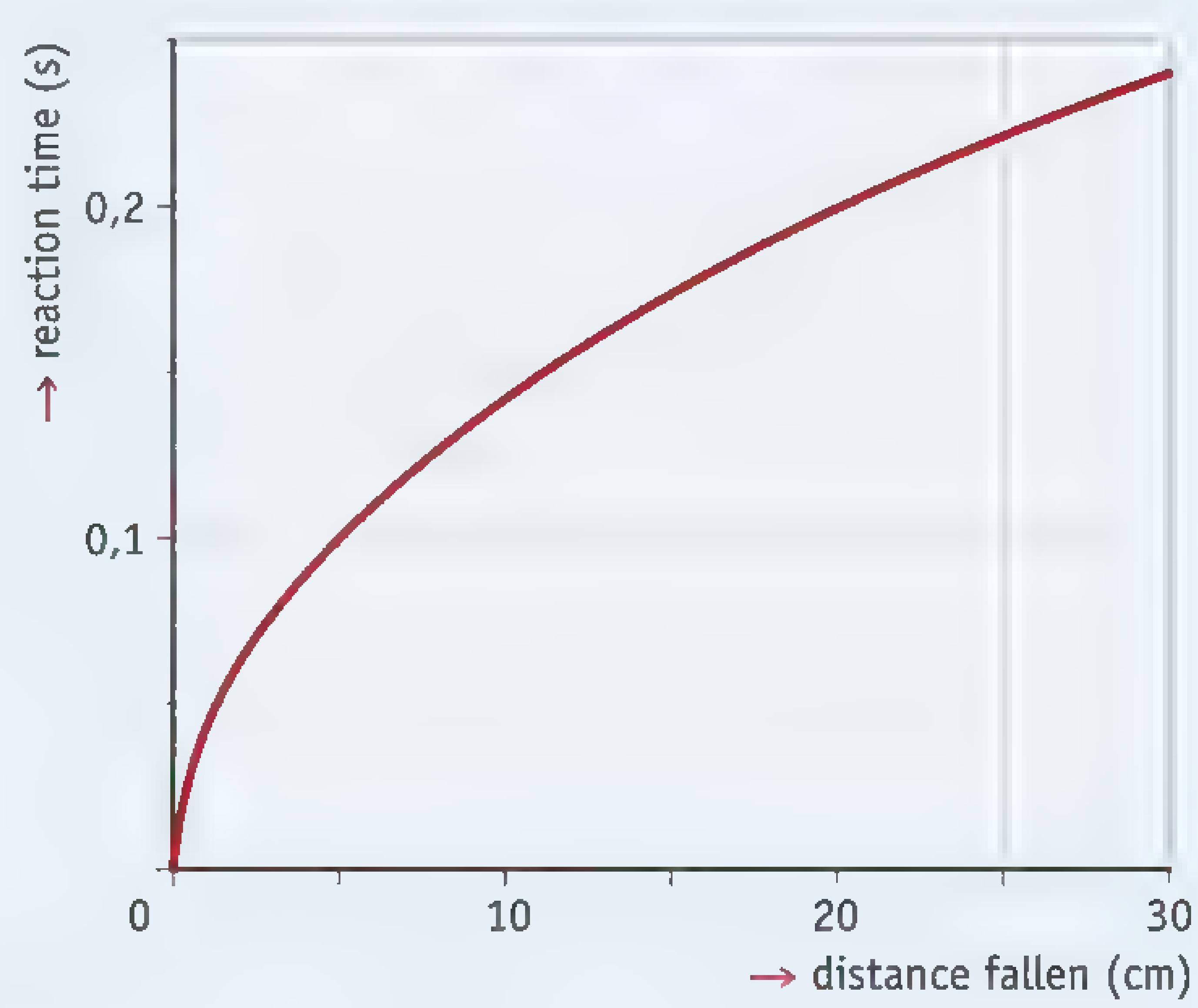
1 Copy table 6 into your exercise book.
Note the distance the ruler dropped in the table.
This distance can be read directly off the ruler.

▼ table 6 the measurements for experiment 5

test subject	distance fallen (cm)	reaction time (s)
pupil 1		
pupil 1		
pupil 1		
pupil 2		
pupil 2		
pupil 2		

- Do this experiment a total of 3 times. Then swap roles. Now repeat the experiment three times, this time with pupil 2 as the test subject.

Writing up
2 See figure 39.
Read off the corresponding reaction time for each distance fallen.
Note the reaction time in the third column of the table.



▲ figure 39
the relationship between the distance fallen and the reaction time

3 Work out the average reaction times below:
   a for pupil 1.
   b for pupil 2.

4 Having a short reaction time is often important. State a situation for which it is important in:
   a traffic.
   b sport.

Experiment 6 Carrying out research: braking distance 45 min

Introduction
Imagine: a traffic safety expert states in a television programme that it is dangerous to take someone else on the back of your bike. This person says that it not only makes you less stable, but also makes the braking distance longer. "That may well be true," you think, "but will it really affect the braking distance that much? It must be possible to investigate that..."

Aim
You are going to look for an answer to the following study question:
What is the percentage increase in the braking distance if you have someone else on the back of your bicycle?

Requirements
For this experiment, you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up
- Think how you are going to be able to provide a reliable answer to the study question. What is your test setup going to look like; exactly what are you going to measure; how will you make sure that the measurements are repeatable (and can therefore be verified)? Hint: read experiment 4 again to get some ideas.
- Talk it through together to discuss any risks that might be involved. What can you do to make sure that this experiment can be carried out safely?

1 Make a work plan for this research.

- The work plans will be discussed with the rest of the class at the next lesson. If necessary, you can make improvements to your own work plan after that.
- Then carry out the experiment.

2 Note down all the measurements, calculations and results in your exercise book.

- Your teacher will tell you whether or not you have to write up a report on this experiment.

Experiment 7 Designing a model of a crumple zone 45 min

Introduction
The crumple zone of a car distorts easily if a collision occurs. This makes the 'braking distance' for the occupants longer, so that the impact of the collision is lessened.

Aim
You are going to design a model of a crumple zone and try it out.

Requirements
- trolley
- sloping surface
- brick
- mass (weight)
- ruler
- various materials (paper, cardboard, aluminium foil, adhesive tape, etc.)

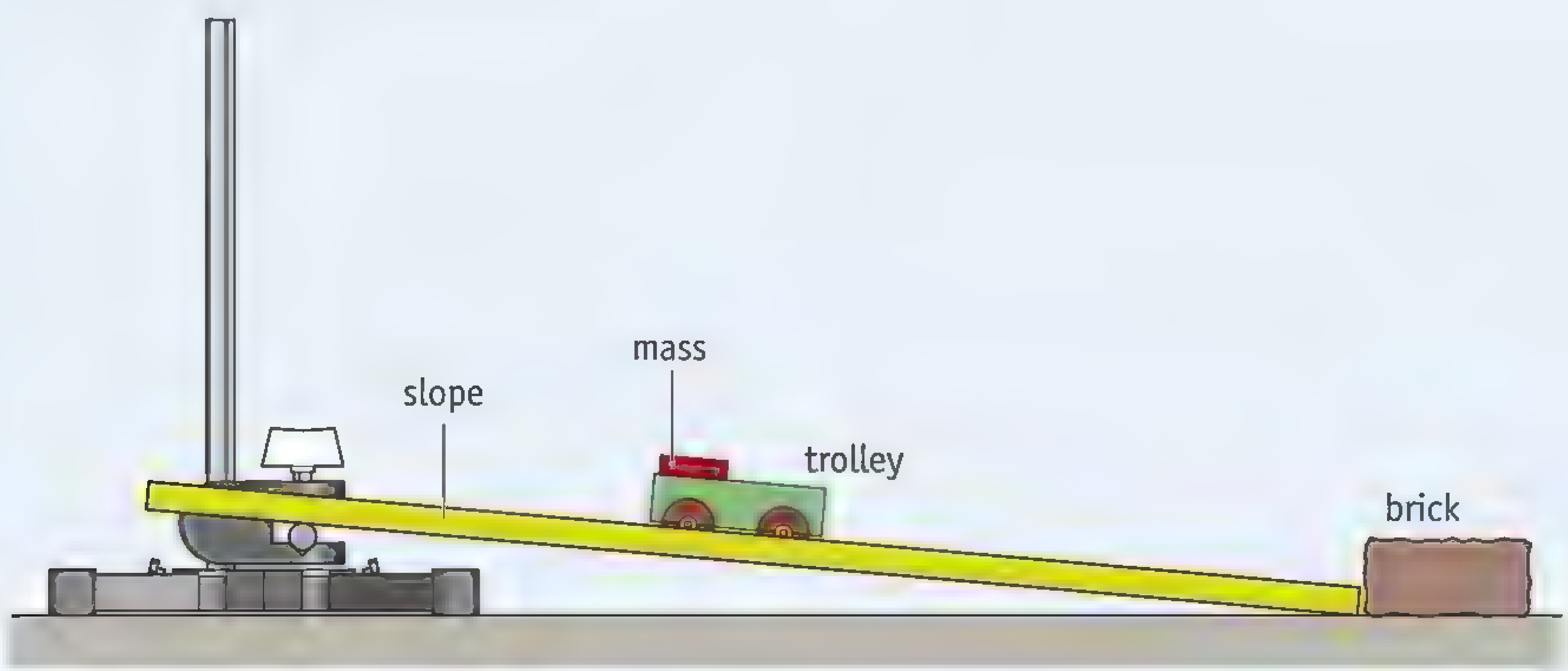
Doing the experiment and writing it up
Preparation
- Create the setup shown in figure 40.
- Place the mass on the trolley (not attached to it).
- Let the trolley roll down the slope and hit the brick.
- Measure how far the mass moved.
- Reduce the angle of the slope if the mass shifted more than 8 cm.
- Raise the angle of the slope if the mass shifted less than 6 cm.
- Repeat the experiment until the shift is somewhere between 6 and 8 cm.

Doing the work
- Think up how you can make a crumple zone on the front of the trolley, using the materials that you have available.
- Construct the crumple zone and test it. Your model must meet the following design requirements:

Design requirements
- The crumple zone must at least halve the amount by which the mass shifts.
- The crumple zone must have the least possible mass (because the car must definitely not be any heavier than necessary).
- The brick must not move when the trolley hits it.

- Improve your design until the crumple zone meets the design requirements.
- If you have enough time, you can also try out other designs. Try to keep the amount of material as low as possible: the less the crumple zone weighs, the better.

Presentation
- Show the class what your crumple zone looks like.
- Explain why you chose these materials and the particular shape, and how you tested and improved the design. When you have tested the various designs, state which one was best and why.



▲ figure 40
the setup for experiment 7

Nova © Uitgeverij Malmberg

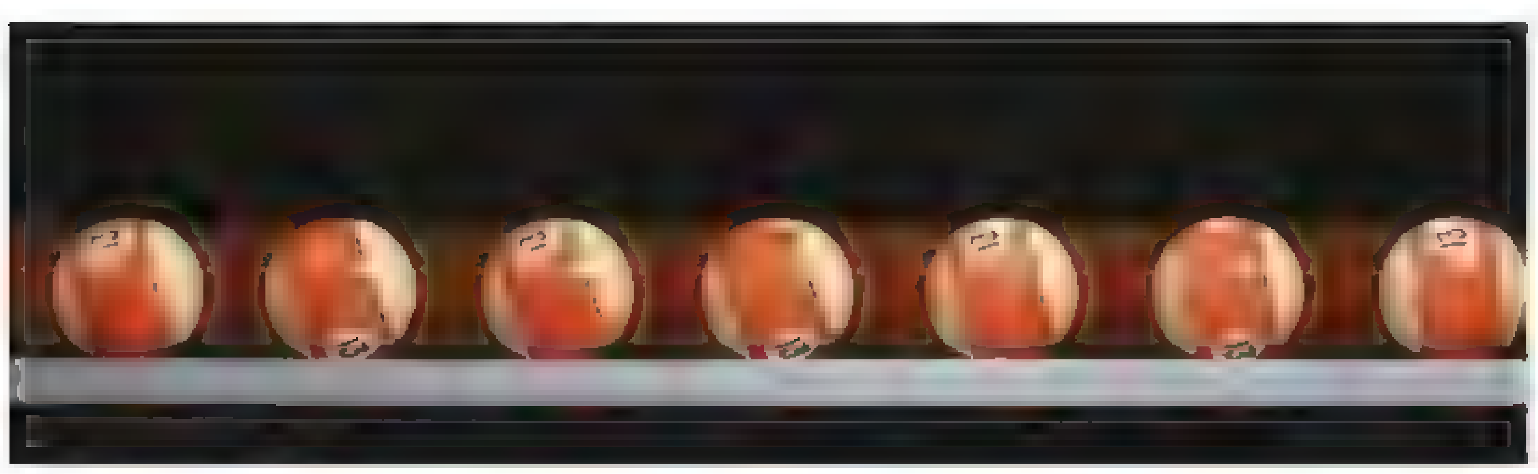
Test Yourself

You can also do questions 1 to 16 on the computer.

1 Megan is making a photograph of a movement. To do this, she is using a light that gives very short flashes of light at regular intervals.
What is the name for this kind of light?

2 Kevin has made a video recording of a falling ball. He wants to make a distance-time table for this falling motion.
What does Kevin need to know before he can do that? Choose between:
- **a** the distance from which the recording is being made? *yes/no*
- **b** the scale of the video images? *yes/no*
- **c** the frame rate? *yes/no*
- **d** the number of frames in the recording? *yes/no*

3 Have a look at the stroboscopic photo of a rolling ball in figure 41. The stroboscope was flashing every 0.1 s.
What is the time difference between the first and the last flashes?



▲ figure 41
a rolling ball

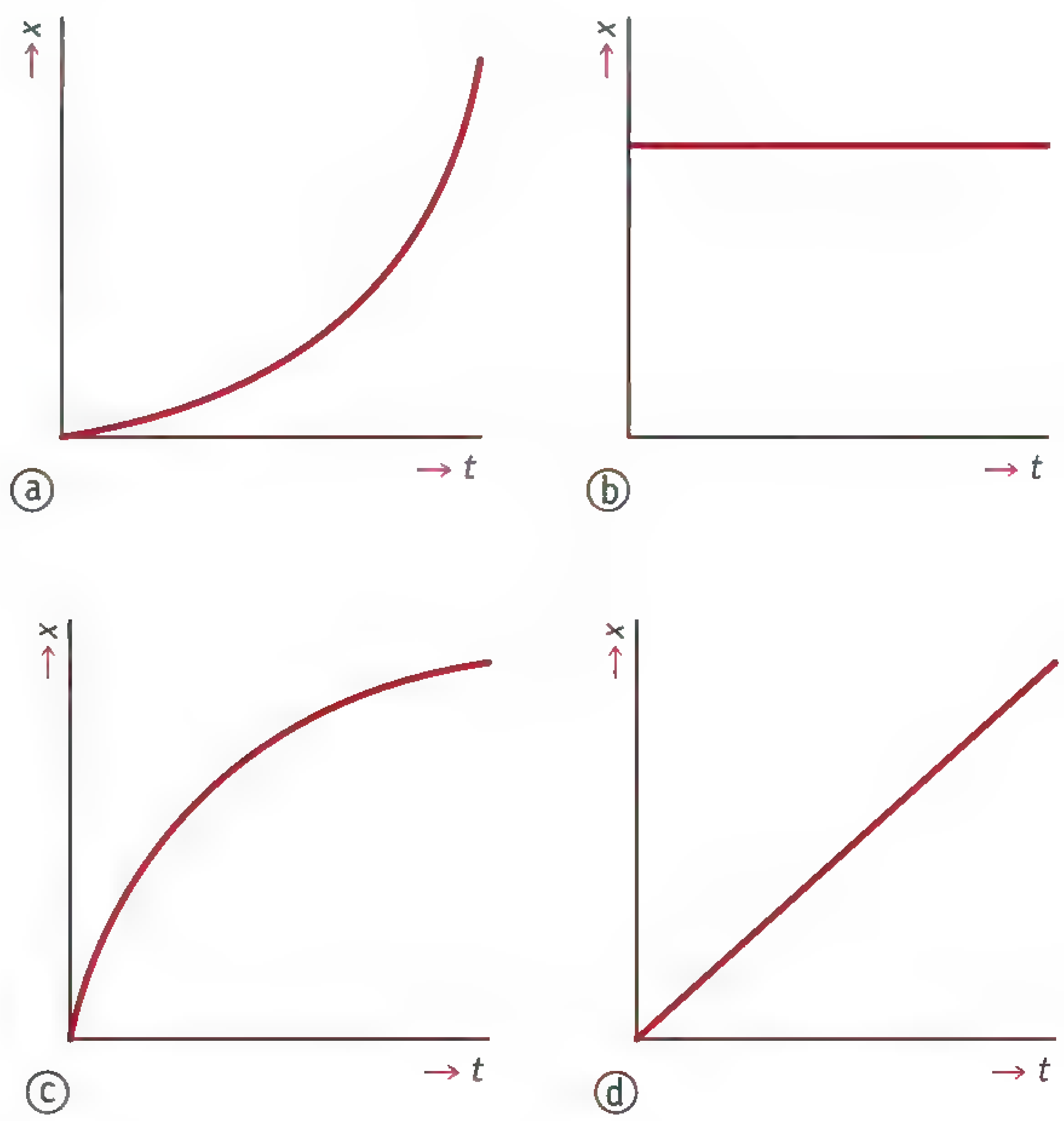
4 Copy and complete:
- **a** 36 km/h = ... m/s
- **b** 126 km/h = ... m/s
- **c** 10 m/s = ... km/h
- **d** 23 m/s = ... km/h

5 The *Varna Tempest* is a specially designed recumbent bicycle (i.e. ridden in a lying position) with very low drag (air resistance). In 2009, the Canadian Sam Whittingham covered a 200-metre test track in it in just 5.4 s.
Calculate the average speed of the Varna Tempest in km/h.

6 Nathan takes a penalty: the ball leaves his boot travelling towards the top corner of the goal at a speed of 90 km/h. The ball will cross the goal line 11.5 m away from the penalty spot if the keeper does not react.
Calculate how long the keeper has to make the save.

7 Patrick cycles straight home from school in twenty minutes. His average speed is 18 km/h.
How far from school does Patrick live?
- A 6.0 km
- B 5.0 km
- C 3.6 km
- D 3.0 km
- E 1.2 km
- F 1.0 km

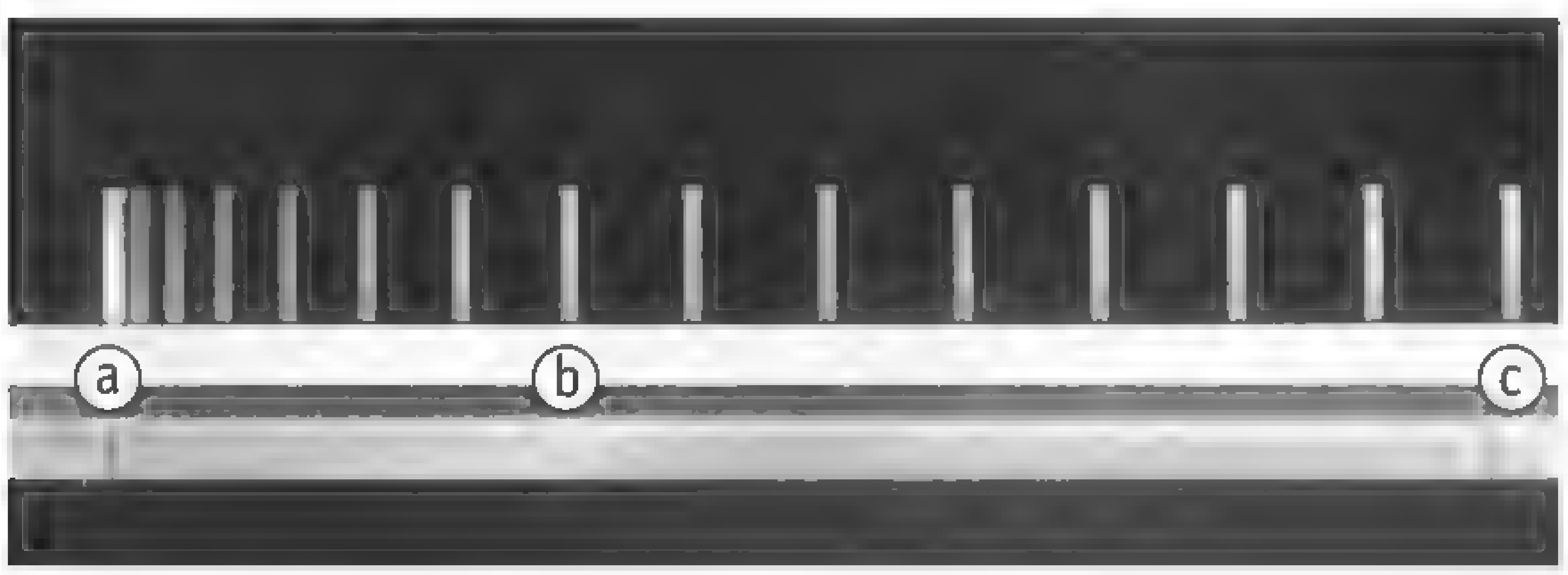
8 Figure 42 shows four (x,t) graphs of various movements.
Which (x,t) graph:
- **a** is of a uniform motion?
- **b** is of an acceleration?
- **c** is of a deceleration?
- **d** is of a stationary object?



▲ figure 42
four movements

9 A lift takes passengers from the ground floor to the sixteenth floor, 50 metres up, in 10 s.
Which statement is correct?
A The greatest speed of the lift is more than 5 m/s.
B The greatest speed of the lift is exactly 5 m/s.
C The greatest speed of the lift is less than 5 m/s.

10 Figure 43 shows you a stroboscopic photo of an experiment with an object moving on an air cushion. The motion starts at a.
Select the correct options.
a Between a and b, the object's motion is *uniform / accelerating / decelerating*.
b Between b and c, the object's motion is *uniform / accelerating / decelerating*.



▲ figure 43
a stroboscopic photo of an experiment with an object moving on an air cushion

11 A group of pupils has recorded the motion of a bicycle. The experiment went as follows:

> The pupils marked out a fifty-metre track. Then they stood at the side of the track with stopwatches at intervals of ten metres. The stopwatches were all started at the same time, when the cyclist crossed the starting line. Whenever the cyclist passed one of the pupils, he or she pressed the button to stop the watch.

The collected measurement data is shown in table 7.
What type of motion is it?
A acceleration
B deceleration
C uniform motion
D you cannot tell from this dataset

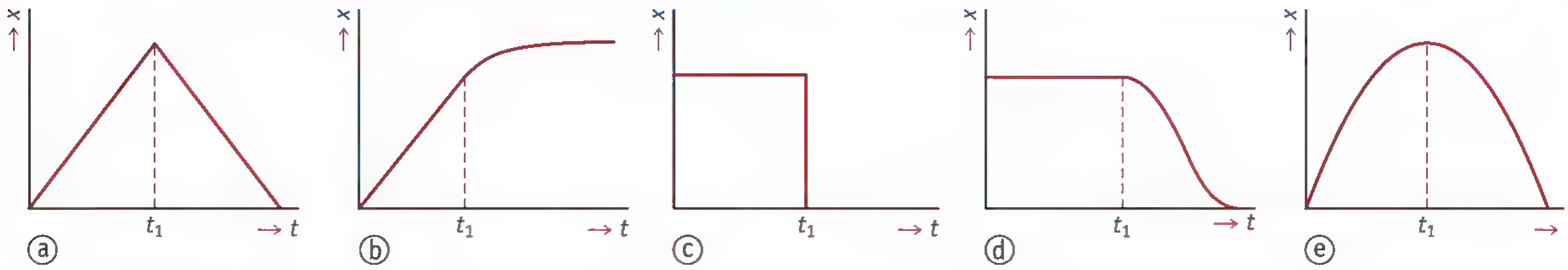
▼ **table 7** a distance-time graph for a bycicle

time (s)	distance (m)
0.0	0
1.26	10
3.11	20
4.93	30
7.37	40
11.43	50

12 Felix is cycling with his girlfriend on the back, going steeply downhill in the pouring rain. The braking distance under these circumstances is much greater than normal.
Why?
Copy and complete:
a Because his girlfriend is on the back, the total mass is ...... than usual.
b Because he is going steeply downhill, his speed is ...... than usual.
c Because of the heavy rain, the braking force of his bike is ...... than usual.

13 A motorist is driving at 80 km/h on a through road. At a given time t_1, she sees the truck in front of her losing part of its load. She reacts quickly, but it still takes a moment, until time t_2, before the brakes of her car are applied. A few seconds later, at time t_3, her car comes to a halt – just in time!
What term is used for the distance that her car travels:
a between time t_1 and time t_2?
b between time t_2 and time t_3?
c between time t_1 and time t_3?

14 Under normal conditions, a car has a braking distance of 40 m at 80 km/h.
What is the braking distance under the same conditions at 40 km/h?



▲ figure 44
Which of these (x,t) graphs represents the braking of the moped?

15 Reuben is driving his moped at a constant speed on a straight road. At time t_1 he starts braking until he comes to a halt.
Figure 44 shows you five (x,t) graphs. In which graph are the distances for the moped shown correctly?

16 There may be various reasons why a car is unable to stop in time. For example:
1 The driver was deeply involved in a phone conversation.
2 The car was towing a heavily-laden trailer.
3 Rain had made the road surface slippery.
4 The car tyres had almost no tread left.
5 The driver had drunk a few glasses of wine.
6 The car was going more quickly than the speedometer indicated.
a Which of these circumstances affect the reaction time?
b Which of these circumstances make the braking distance longer?

17 Jessica and her brother Tom live 800 m from school. One morning they leave at the same time: Tom goes by foot, walking at a steady speed of 2.0 m/s. Jessica goes by bike, cycling at a steady speed of 8.0 m/s. But after 45 seconds, her bike chain gets stuck and it takes her 4.0 minutes to fix it. Then she continues, cycling at 8.0 m/s again.
a Draw the (x,t) graphs of the two motions.
b At what time does Tom overtake Jessica?
c Who gets to school first and how many metres does the other still have to go at that point?

18 Police speed checks often measure the average speed over a section of road. These use cameras at the start and end of the road section, 3.0 km apart, which record the passing traffic. A computer calculates the average speed for each vehicle. If that speed is greater than the speed limit, the driver is going too fast and automatically gets a fine in the post.
a The speed limit on a road segment is 100 km/h. Calculate the shortest time that a car may take to cover the segment.
b One driver is doing 160 km/h at a particular moment on the road section.
Is it certain that he will be fined? Explain your answer.
c Another car driver covers the first half of the section at 120 m/h.
Calculate how fast he can drive (on average) on the second part of the section if he is not to get a fine.

19 Figure 45 shows you a stroboscopic photo of a toy duck that is being thrown into the air.
a At what moment was the toy duck moving fastest and how can you see that?
b At what moment was the toy duck moving slowest and how can you see that?

20 Jason and Stacy are running towards each other. At a given moment (t = 0 s), they are 45 m apart. Stacy runs at a steady speed of 2.5 m/s. Jason runs at a steady speed of 3.5 m/s.
Use a graph to determine how many seconds it will be before they meet.

▼ figure 45
a toy duck being thrown into the air

Aerial acrobats in SLOW MOTION

A group of geese are landing. Just before the birds come down onto the water, one goose does an astonishing aerial acrobatic stunt. It flies upside down, with its belly up and its feet pointing to the sky. Only the head is still looking forward as normal, because its neck has twisted through 180 degrees. This seems to be a unique trick, but that is not remotely the case: a couple of other geese immediately follow suit.

The aerobatics of the geese have been recorded in slow motion thanks to a unique project called *De Vliegkunstenaars* (Flight Artists) at Wageningen University. This project loaned high-speed cameras to volunteers: nature lovers, amateur photographers, artists and others who were interested. Their assignment was to make recordings of aerial acrobatics in nature.

The project participants filmed a very wide range of subjects – recordings were made of a fly doing a somersault, an aerial combat between sparrows, and a honey bee colliding with a bumble-bee. Researchers are using the pictures to study how birds and insects fly. Normally, the wings move much too fast for this to be seen properly.

Slow motion

A normal video recording such as a YouTube clip consists of 24 to 30 pictures a second. If you watch a recording like that at the normal speed, you do not see the individ-ual frames. Instead, you see a fluid movement. That changes if you play the recording back ten times more slowly. Then you do see a sequence of individual pictures that do not give the appearance of a fluid motion.

A high-speed camera is designed to record movements that are too fast to follow with the naked eye. To do this, the camera has to record far more images than a normal video camera. For example a recording may be at 300 frames a second. If you then play that recording back ten times more slowly, one second seems to last ten seconds. Because it is being played back at $300 \div 10 = 30$ frames a second, the motion still appears fluid.

This kind of representation – slowed down but still fluid – is called *slow motion*. Slow motion is not only useful in science for recording motions so that they can be investigated. The same technique is often used in films, for example to make a dramatic scene even more impressive or to allow every detail of an action scene to be seen.

DID YOU KNOW...

One of the most famous slow motion scenes comes from the film *The Matrix* (1999). In this scene, the camera seems to be moving around the main character, Neo. This scene was not made using a single high-speed camera. Instead, it used 120 different cameras that took pictures in turn, each one shortly after the previous one.

Flight Artists

More than 2000 clips were made by 460 volunteers for the Flight Artists project. These clips are freely available on the Internet and may be used for class presenta-tions, for scientific research and anything in between! It means that you can now calmly enjoy the wonderful flying motions of the everyday flying artistes around us, from butterflies to sparrows and from bats to sycamore seeds.

The recordings have yielded all sorts of new information. It has been known for some time, for example, that geese occasionally fly on their backs, but the research-ers knew very little more than that, because the geese perform the manoeuvre so quickly that it is almost impossible to follow with the naked eye. One of the volunteers managed to film this behaviour for the first time with a high-speed camera. Thanks to him, the entire flying movement can now be seen in slow motion.

The Wageningen researchers are primarily interested in how the wings of birds and insects actually move while flying. Slow motion recordings are an indispensable tool for them. David Lentink, who set up the project, says, “We have recordings of a wasp, for example. It has two pairs of wings, just like other insects, but when it flaps them – warming up before taking off – the wings catch and interlock, effectively making them just a single wing pair. I had never seen that before.”

The wings of birds and insects function very differently to the rigid wings of an aircraft. They are lightweight, flexible structures that are able to make all sorts of complex movements. The wings do not merely move up and down as the animal flies, but they also twist and are distorted in various ways during the motion as well. All these movements are very effective: many birds and insects are real aerial acrobats – fast and highly manoeuvrable.

Flying like a dragonfly

Knowledge such as that accumulated by the Wageningen researchers is interesting for other people besides nature lovers. That knowledge is currently also being applied in designs for ultra-small aircraft. The very smallest of these imitate the way in which birds and insects fly. They do not have large, fixed wings like a normal aircraft but instead use small moving, flexible wings. Slow motion recordings of birds and insects are hugely valuable in the quest for optimum wing designs.

Slow motion recordings of birds and insects are hugely valuable in the quest for optimum wing designs.

And that search is already starting to bear fruit. One example is the *Delfly Micro*, a miniature aircraft ten centimetres in length and with a mass of three grams, which flies like a dragonfly. Since 2008, it has been officially recognised as the smallest flying robot with a camera in the world. The design team at Delft Technical University hopes that the *Delfly Micro* will be able to help the fire brigade find the sources of fires in burning buildings or to locate survivors in collapsed buildings. This tiny robot could also be used by the police, for example to reconnoitre a house before carrying out a raid.

Increasing numbers of robots are now being developed that fly like insects or birds. At Leuven University in Belgium, the student Frederik Leys developed a flying robot weighing four grams that was inspired by the way a hummingbird flies. One group of researchers in the United States are busy developing the *Robobee*, a flying robot of less than 0.1 gram that is based on the way bees fly. The idea is that these robo-bees will behave as a colony – the same hive behaviour as real bees.

So clips that have been made using high-speed cameras do more than just provide interesting visual material: they can also lead to surprising insights. In the future, ultra-small aircraft may be able to carry out all sorts of tasks that we are currently only able to dream of – all based on the aerobatics of birds and insects.

A water balloon bursting

High-speed cameras are also used for all sorts of other studies. For example impressive clips have been made of balloons of water bursting. To the naked eye, it looks as if the balloon bursts in a single moment and the water cascades downwards. However, film clips taken at very high speeds show that the balloon first rips open and the water hangs there in the shape of the balloon for a moment.

Exercises

1 A video has been recorded at 450 frames per second and is played back at 30 frames per second.

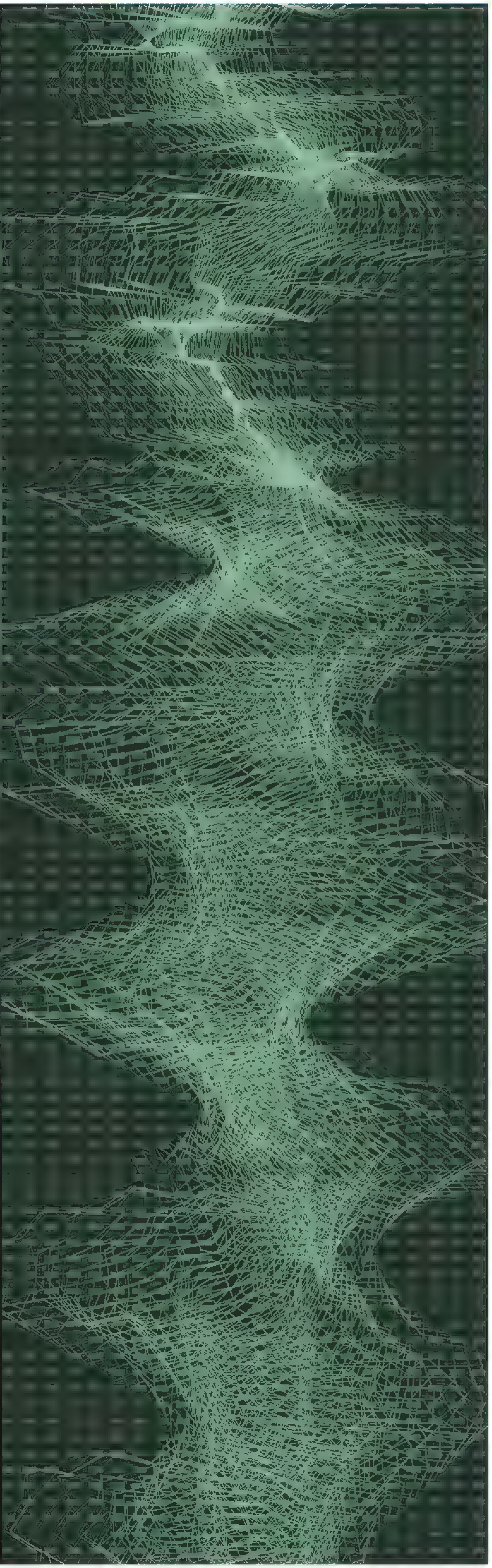
a How much slower does the movement recorded on the video clip now seem?

b There are already professional cameras available that can film at a million pictures per second.
How much slower would the motion recorded with that type of camera appear when played back at thirty pictures per second?

2 The cameras used for the *Flight Artists* project make recordings at 600 pictures per second. On a clip made with one of these cameras, a bumblebee takes 12 frames to move 10 cm.
Calculate the average speed of the bumblebee. Give your answer in m/s and km/h.

3 The *Delfly Micro* can stay airborne for three minutes.
Explain what the difficulties are in making such a small aircraft fly for longer.

Nova © Uitgeverij Malmberg



7 Sound

Sound around you

A world without sounds is difficult to imagine. What would the world be like without music, without a nice chat, without the sound of the wind and that of the sea? And also without the racket of cars racing past, planes taking off and antisocial neighbours?

1 Making and hearing sounds

Sound is everywhere in nature. Think of thunder rumbling, the crashing of waves on the seashore and all the animal noises. People make and create sounds as well. They talk, sing, shout, make music, drive cars, let off fireworks and so forth.

▲ figure 1
When a loudspeaker is producing a sound you can feel the cone vibrating.

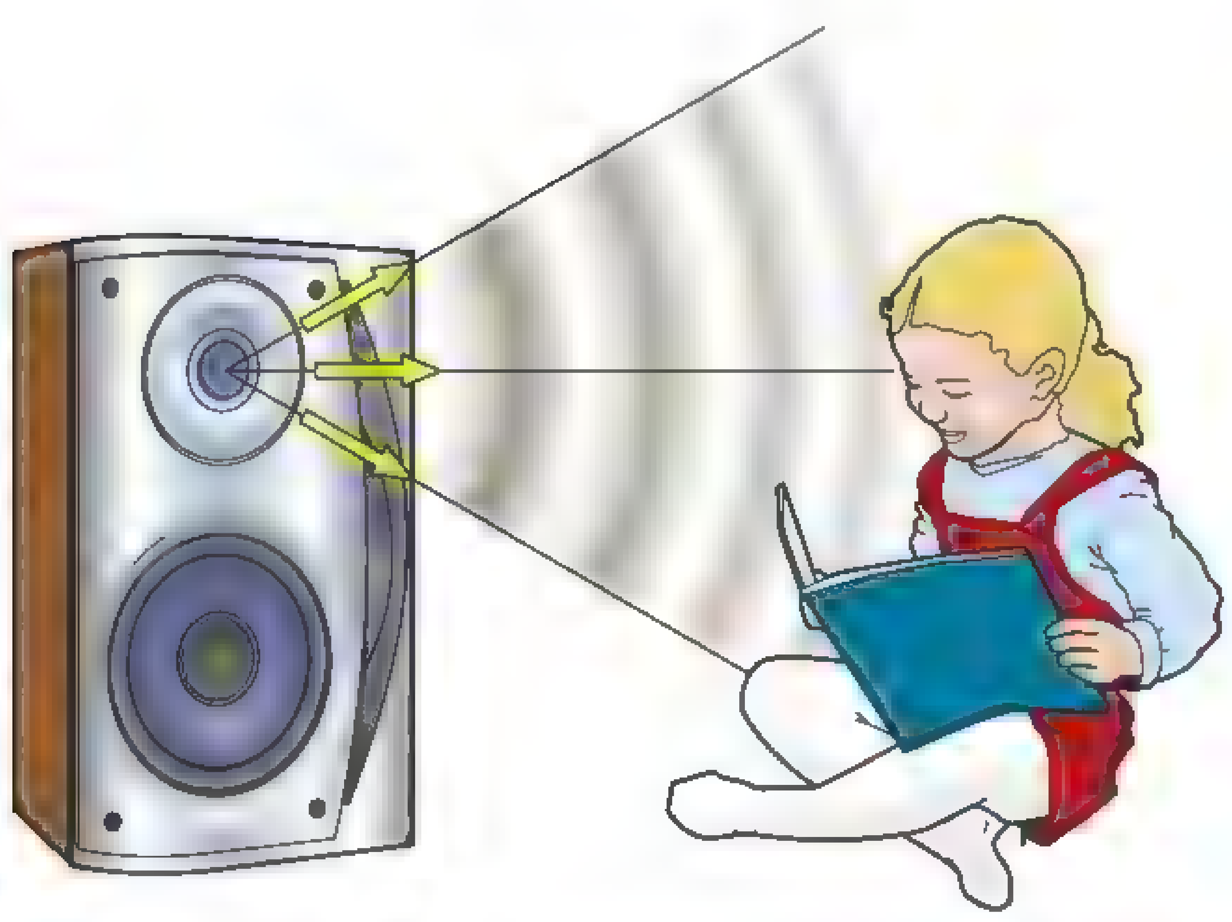
Sound sources   Experiment 1

An object that makes a noise is referred to as a **sound source.** Many sound sources are made by humans, such as musical instruments, firecrackers, motorbikes and loudspeakers. Other sounds come from natural sound sources, such as the sound of your voice, birdsong or thunder.

Sound is produced by vibrations in a sound source:
- In the case of your voice, the vibrations are in your vocal cords.
- In a loudspeaker, the part than vibrates is the cone (figure 1).
- In a guitar, the strings vibrate (making the soundbox vibrate).

From the sound source to your ears   Experiment 2

The cone of a loudspeaker is a thin sheet of paper or plastic. When the loudspeaker is producing a sound, the cone is moving back and forth rapidly. This creates pressure differences in the air. When the cone moves outwards, the molecules next to it are forced closer together (which increases the air pressure). Conversely, when the cone moves inwards, conversely, the molecules are more spaced out (so the air pressure drops). The drawing in figure 2 shows how the sound from a loudspeaker spreads.



▲ figure 2
The pressure changes are propagated from the sound source to the receiver.

Because the molecules are continually colliding with one another, their movements get passed from one to the next. The movements of the molecules close to the cone are passed on to the molecules that are further away from the cone. The net result is that the pressure changes move away from the loudspeaker in all directions, and when those pressure changes reach your ears, you hear the sound.

You can only hear sound when there is a **medium** to carry it: a substance that the vibrations can pass through from the sound source to your ears. Most sounds reach your ears through the air. But sound can also travel through liquids and solids. For example you hear the sound of your voice not only from the outside (through the air) but also from the inside (through your skull). For instance deaf people can sometimes feel the rhythm of the music through a disco floor.

The speed of sound

Sound takes time to propagate through a medium. The speed at which sound travels varies from one material to another. The **speed of sound** in air is approximately 340 metres a second. That's more than 1200 km/h!

You can use sound to calculate the distance between the sound source and the receiver. To do that, you have to know the speed of sound and know (or measure) how long sound took to travel from the source to the receiver. Then you use the formula:

distance = speed (of sound) × time

or in symbols:

$s = v \cdot t$

If you use the speed of sound v in metres per second and the time t in seconds, you get the distance s in metres. Table 1 shows you what the speed of sound is in various materials.

▲ figure 3
The sound of thunder comes towards you at a speed of 340 m/s.

Worked example

Isabelle is out for a walk at the end of a hot day. She sees lightning strike in the distance (figure 3). She counts three seconds before she hears the thunder.
How far away from Isabelle did the lightning strike?

given $v = 343$ m/s
$t = 3$ s
required $s = ?$

working
$$\begin{aligned} s &= v \cdot t \\ &= 343 \times 3 \\ &= 1029 \text{ m} \end{aligned}$$

So the distance was roughly 1 km.

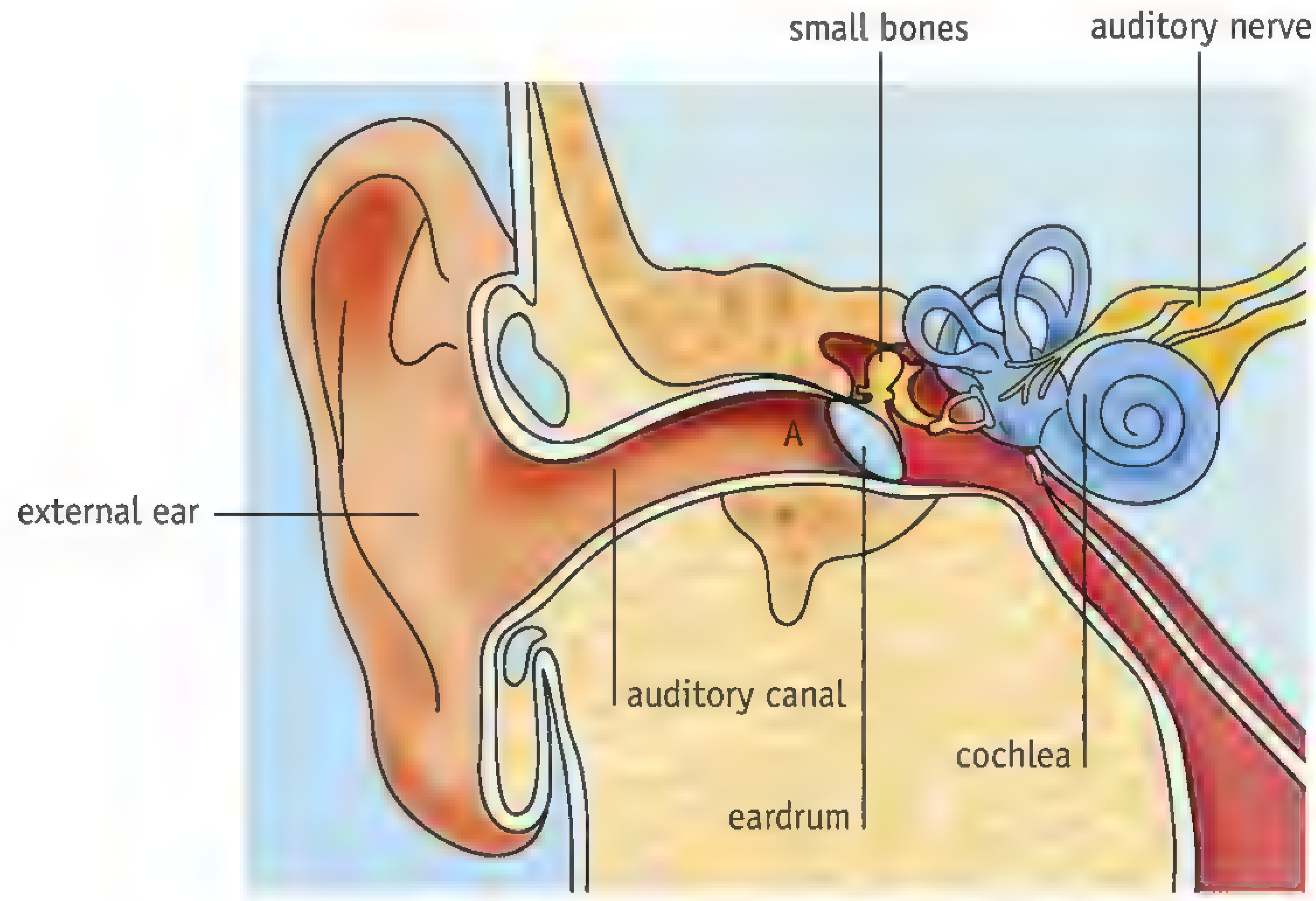
As you can see, there is no need to make any allowance for the time that light needs to get to your eyes. This is because the speed of light is so fast: about 300,000 km/s!

▼ **table 1** the speed of sound in various solids, liquids and gases at 20 °C

substance	speed of sound (m/s)
solids	
concrete	4300
glass	4000-4500
cork	500
rubber	50
steel	5100
liquids	
alcohol	1170
water	1480
seawater	1510
gases	
helium	965
carbon dioxide (CO_2)	259
air	343

Hearing sounds

Figure 4 is a drawing of the inside of an ear. When the sound waves reach the ear, the eardrum vibrates along with them.
- The eardrum moves inwards when the air pressure at A increases.
- The eardrum moves outwards when the air pressure at A decreases.



▶ figure 4
the inside of your ear

The eardrum therefore vibrates along with the changes in the air pressure. The small bones in the ear transmit the vibrating movement of the eardrum to the liquid in the cochlea. This also amplifies the sound.

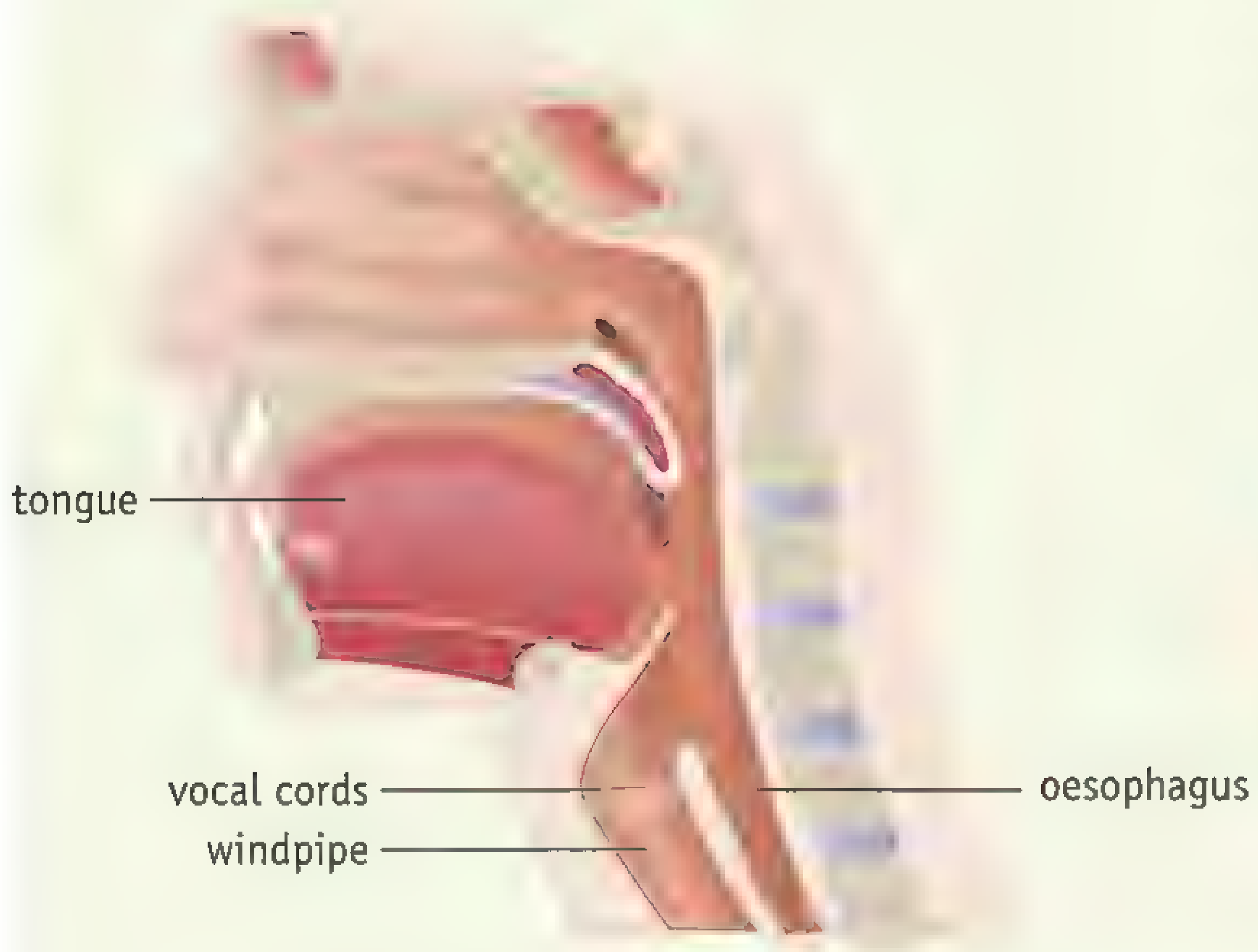
Auditory cells in the cochlea translate the vibrations into electrical signals. These signals are transmitted along the auditory nerve to the brain. You only become aware of the sound when your brain receives these signals: you hear the sound.

Plus The human voice Experiment 3

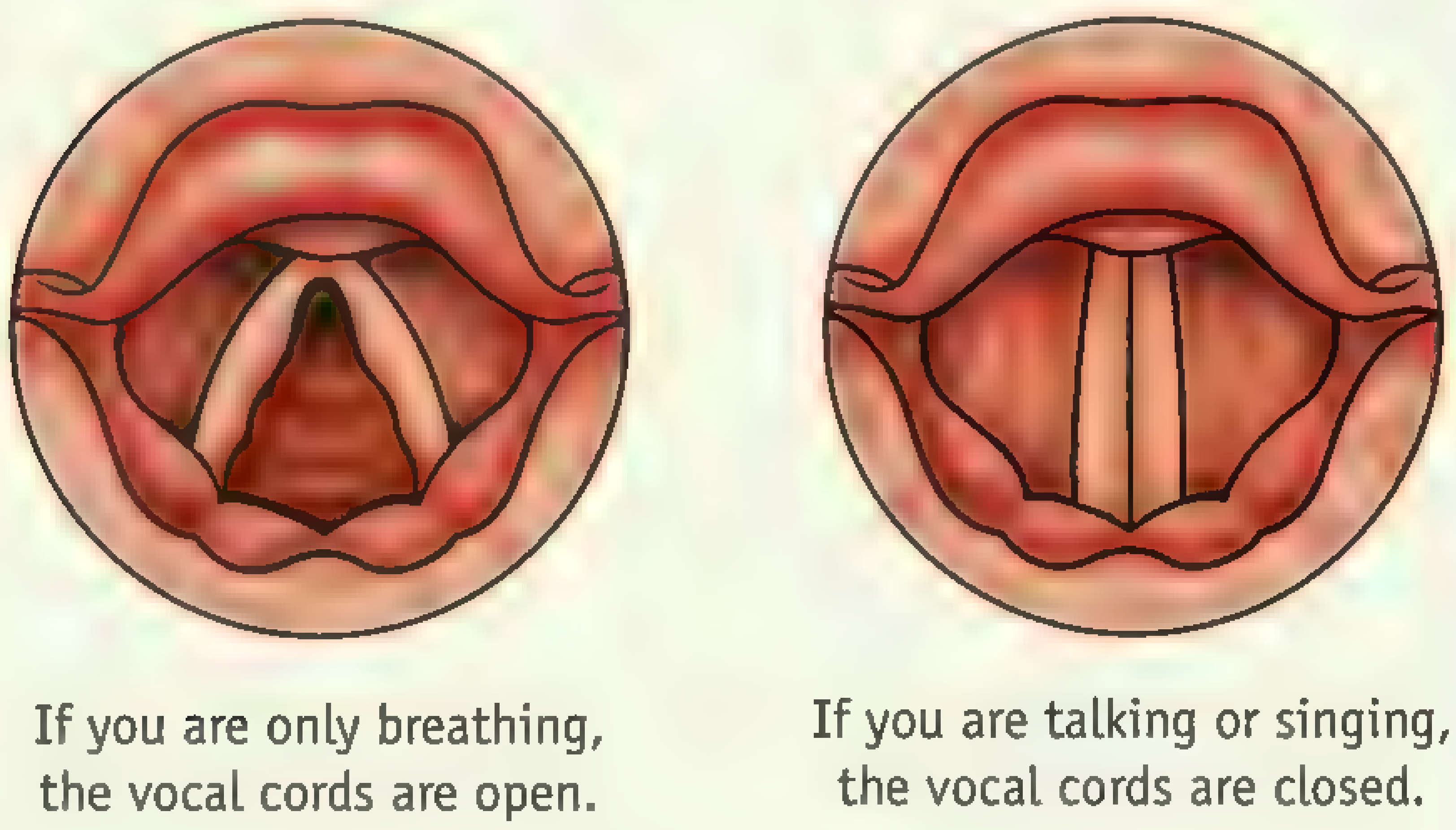
The 'speech organ' comprises the vocal cords, the cavities in the mouth, throat and nose, and the tongue and the lips (figure 5). When you speak, you vocal cords contract. Your lungs then force air through the glottis, the small gap between the vocal cords (figure 6). Your vocal cords then begin to vibrate, as you will be able to feel if you touch your throat with your fingertip.

There are muscles that let you alter the tension of the vocal cords, which lets you control the pitch of your voice. Changing the shape of the cavity in your mouth lets you distort the sound of the vocal cords. Try making a long vowel "ah" and then a long vowel "oh". You will be able to feel the shape of your mouth cavity changing.

You can also make sounds without using your vocal cords, for example when you say an 's' or a 'p'. For a 'p', you close the airflow off with your lips, so that a small amount of pressure accumulates behind them. That pressure is released when you relax your lips. The result is an 'explosion' of air flowing outwards.



▲ figure 5
the organs of speech



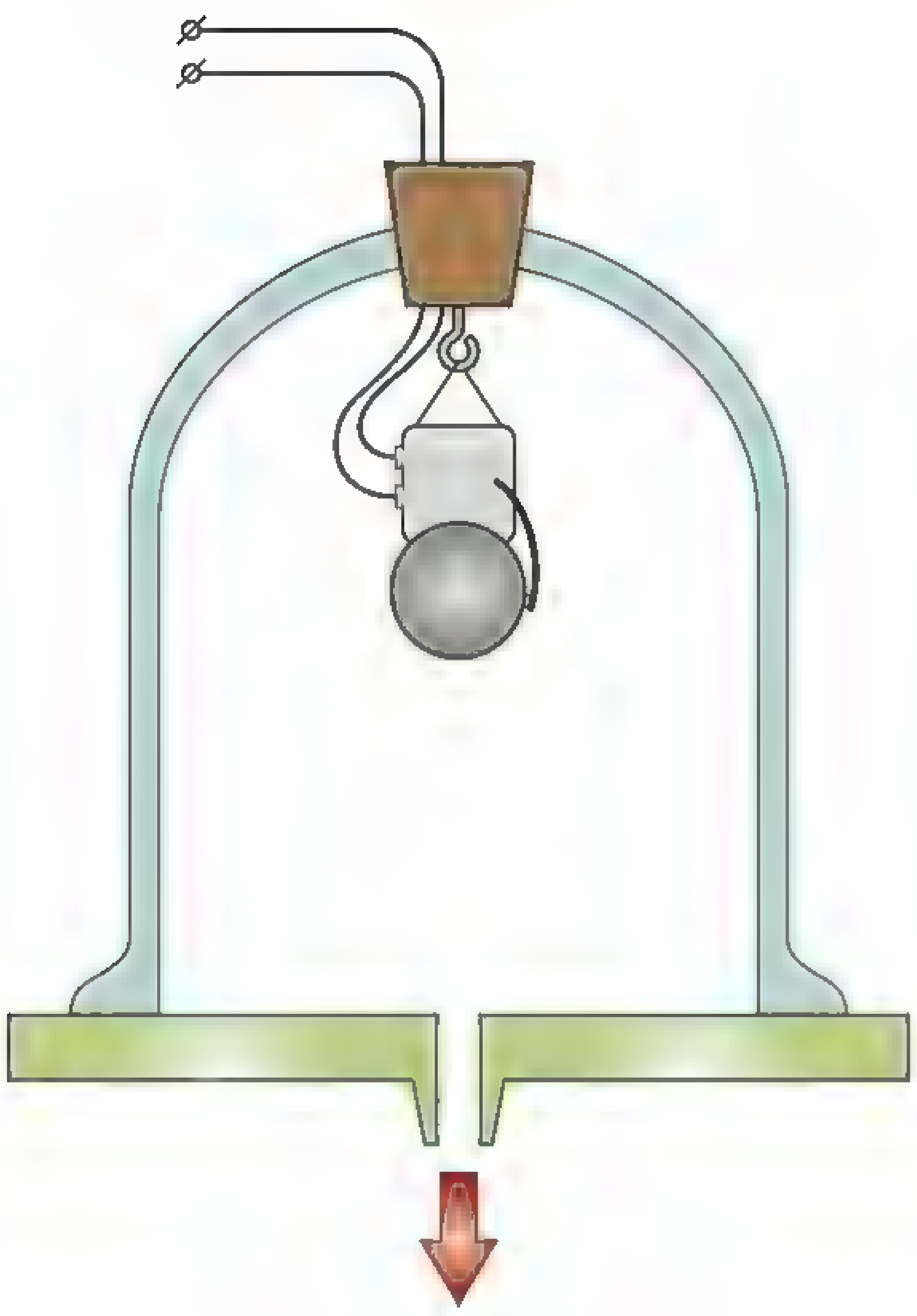
▲ figure 6
How your vocal cords work.

Exercises

1 Sound is caused by vibrations. What is vibrating in:
- **a** an acoustic guitar that is being played?
- **b** a loudspeaker through which music is being played?
- **c** your throat when you are talking or singing?

2 A loudspeaker is an example of a sound source.
- **a** What are created in the air when the cone starts vibrating?
- **b** How does sound travel from the loudspeaker to your ears?
- **c** Which part of your ear vibrates when the sound arrives there?
- **d** Where in your ear are the vibrations turned into electrical signals?

3 In strip cartoons about the Wild West, you sometimes see someone putting an ear down to the rail tracks so that they can hear a train coming from a long way away.
  a What medium is the sound being propagated through in this case?
  b How fast does sound travel through that material?
  c A train is 3 km away from the person who has put his ear to the track. Calculate how long the sound of the train takes to reach that person.



▲ figure 7
a bell under a bell jar

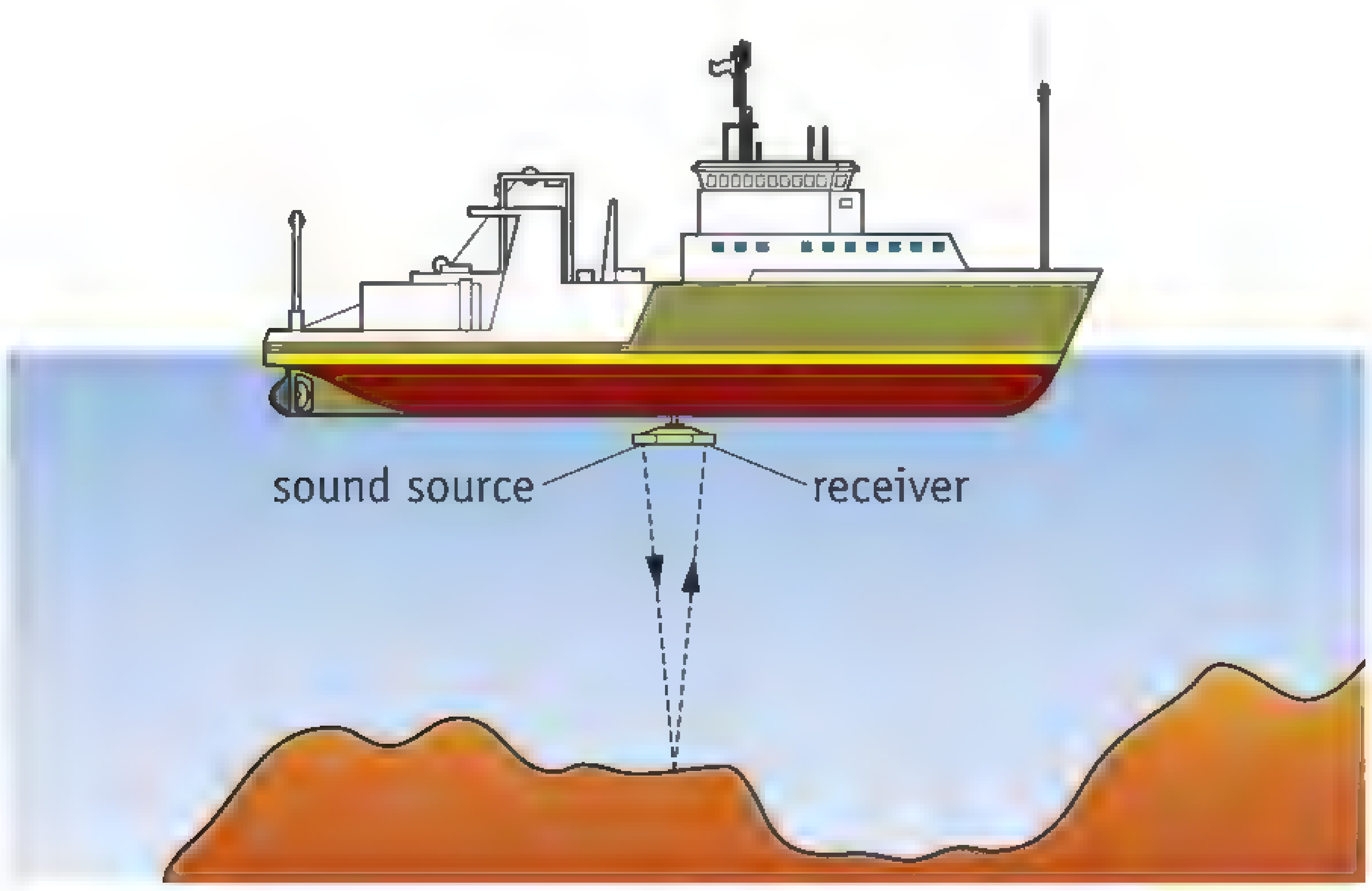
4 Harry is setting up the experiment shown in figure 7. He sets the bell ringing and pumps the air out from inside the bell jar.
  a What change will there be in the sound that Harry can hear?
  b Why?

5 A doctor uses a stethoscope to listen to a patient's heartbeat. What three media has the sound travelled through before it reaches the doctor's eardrums?

6 There is thunder in the distance. Fatima sees a flash of lightning. She hears the thunderclap eight seconds later. Work out how far away Fatima is from the thunderstorm. Give your answer in kilometres.

7 Gerry says, "It's easy to work out how far away you are from a thunderstorm. Count the seconds between the lightning flash and the thunder, and then divide that by three. That gives you the distance in kilometres."
  a How long is Gerry saying it takes sound to travel 1 km?
  b Is that consistent with the speed of sound stated in table 1? Do a sum to show this.

8 A ship is using sound to measure the depth of the ocean. The sonar system sends out a short pulse of sound and then picks up the reflected signal (the echo) a little later. Have a look at figure 8. The time between emitting the sound and receiving the echo is 0.42 s. Calculate how deep the ocean is, in kilometres. Round your answer to two decimal places.



▶ figure 8
How deep is the ocean?

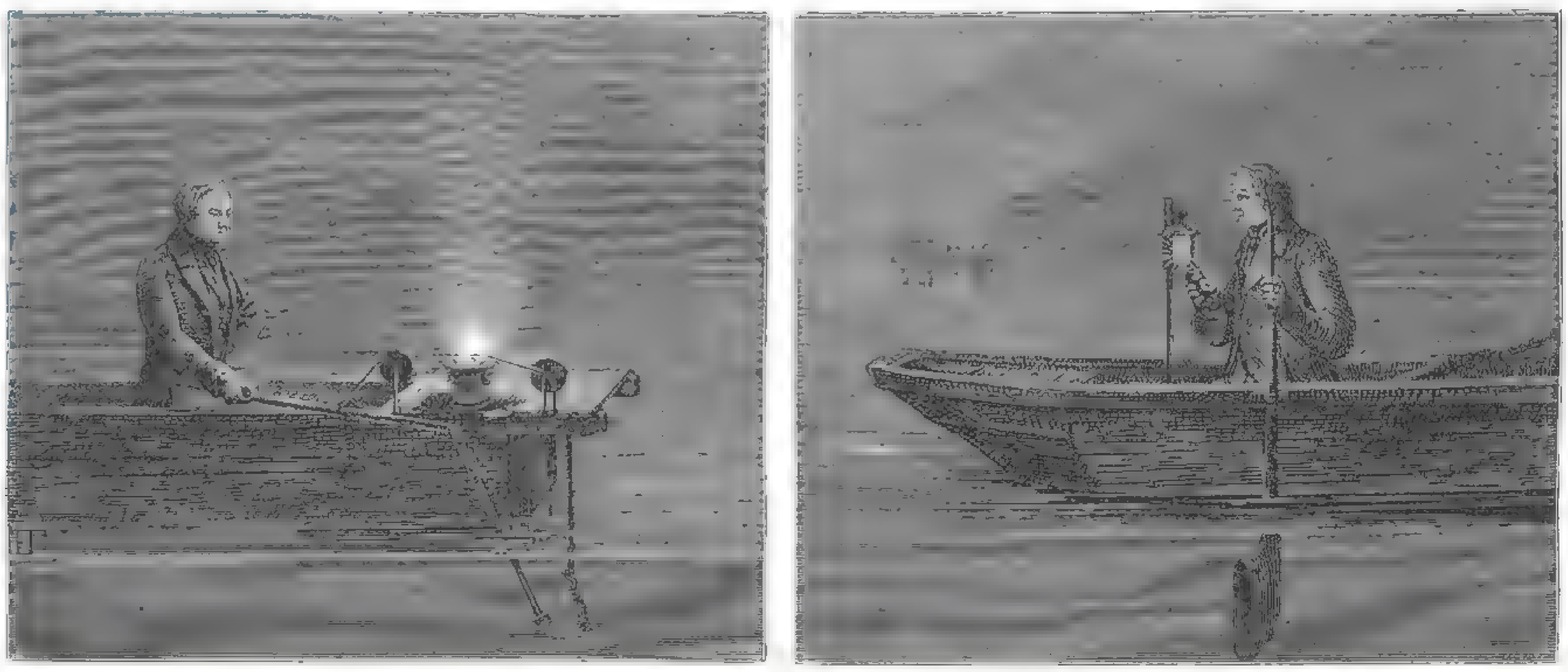
***9** A building has concrete walls that are 50 cm thick. There is a layer of cork 10 cm thick on the inside of the wall. Fiona is sitting 3 m from the wall. Somebody then knocks on the outside of the wall.
Calculate how long the noise takes to reach Fiona. Round your answer to two decimal places.

***10** The scientists Colladon and Sturm measured the speed of sound in water in 1827 on Lake Geneva. They used a bell and a tube. The bell made a noise under the water and the tube let them hear it under the water. A visual signal was given at the same time as the bell was rung (figure 9). Their measurements said the sound of the bell took 9.3 s to travel a distance of 13.4 km underwater.

a Why did they not have to make any allowance for the time that the light from the signal took to reach them?
b What value did they determine for the speed of sound in water?
c The speed of sound depends on the temperature of the water/ Roughly how cold must the lake water have been? Use table 2.

▼ **table 2** the speed of sound in water at various temperatures

water temperature (°C)	speed of sound (m/s)
0	1403
20	1484
40	1529
60	1540
80	1555



▶ **figure 9** Colladon and Sturm at work.

Plus The human voice

11 People can use their speech organs to produce all sorts of sounds.
Where is the sound created:
a when you whistle?
b when you cough?
c when you make a hissing sound (letter ‘s’)?
d when you say the letter ‘A’?

12 Hughie’s class presentation was recorded. When the clip is played back, he does not like what he hears at all. “My voice sounds completely different to what I normally hear when I’m talking,” he grumbles.
Why does your voice sound so different when you hear a recording of it?
Hint: think of the media that are involved in transmitting it.

Nova © Uitgeverij Malmberg

2 Pitch and frequency

If you want to describe a sound, there are various words you can use. Those words often have something to do with the pitch. For example you might say that a broken loudspeaker squeals (makes a high note), rumbles (makes a low note) or buzzes (somewhere in between). The pitch would seem to be an important property of the sound.

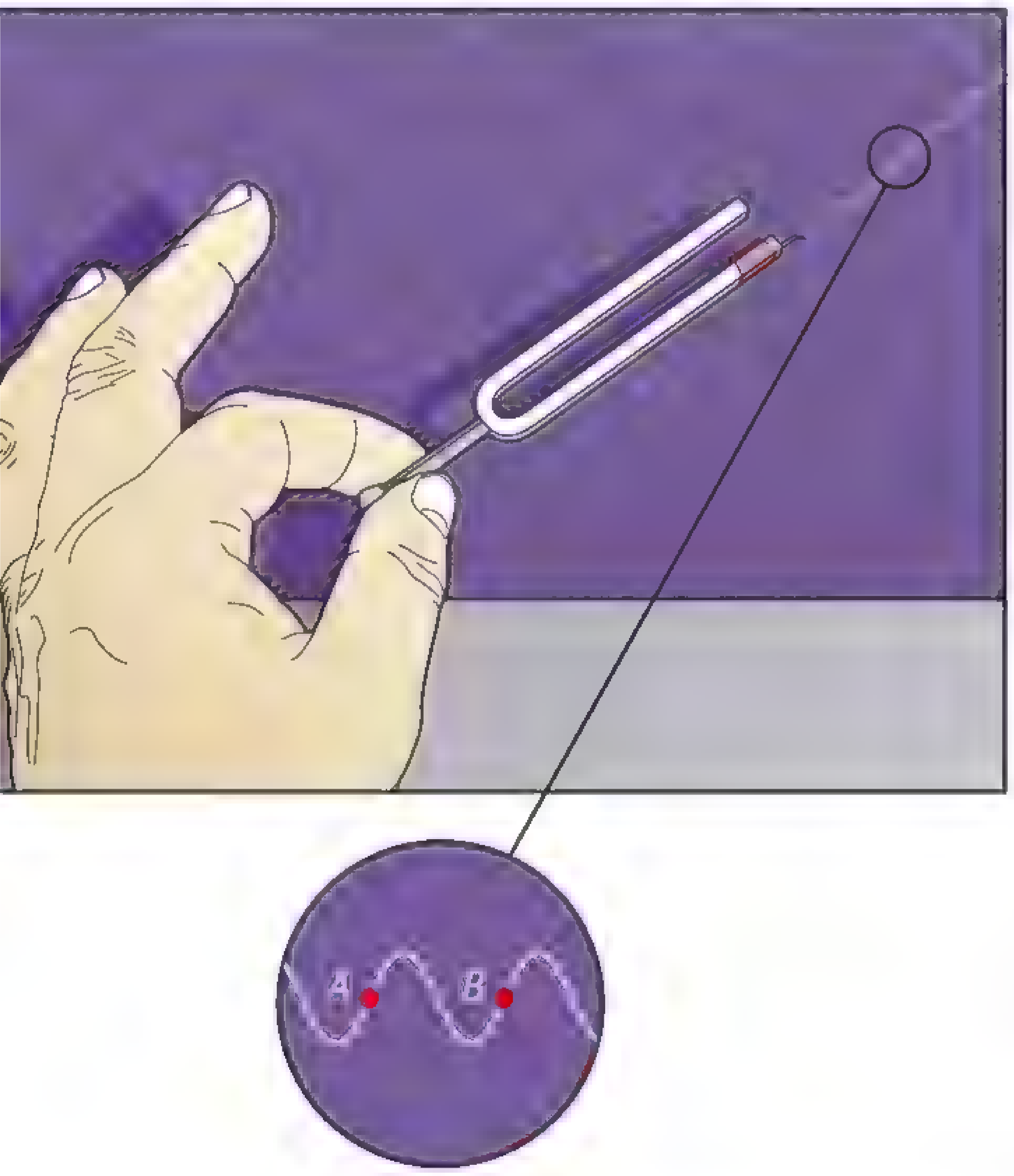
▲ figure 10
A guitarist changes the pitch by altering the length of the string.

String instruments Experiment 4

All sorts of musical instruments use strings, for example a violin has four strings. A guitar usually has six and a piano has more than two hundred. If you make a string vibrate, it produces a tone: a sound with a definite pitch. Most people can then sing the same note without much difficulty.

The pitch of the tone that a string produces depends on three factors:
- the **thickness** of the string: the thicker the string, the lower the pitch.
- the **length** of the string: the longer the string, the lower the pitch.
- the **tension** in the string: the lower the tension, the lower the pitch.

A stringed instrument is **tuned** by adjusting the string tensions correctly (figure 10). You can use a tuning fork or an electronic tuner to determine the correct pitch.



▲ figure 11
This lets you visualise the vibrations of a tuning fork.

Frequency Experiment 5

When you strike a tuning fork, the arms of the tuning fork start to vibrate. They always move back and forth the same number of times in one second. You can investigate this motion using a tuning fork with a wire hook attached to one of the prongs. You can then strike the tuning fork and drag the wire hook along a glass slide with lamp black (soot) on one side. You will see that it leaves a wavy trail.

Figure 11 shows you part of a wavy track made this way. The stylus has made one complete vibration between A and B. If you draw the tuning fork plus wire hook along the glass slide for exactly one second, you will record a large number of vibrations. If you count them, it will tell you exactly how many vibrations there are per second. This is called the **frequency** (f) of the vibration.

Frequencies are measured in hertz (Hz). If the frequency is 128 Hz, this means that the prongs of the tuning fork move back and forth 128 times every second. The higher the frequency, the higher the pitch of the tone you hear. For example, a 440 Hz tuning fork gives a higher note than a 128 Hz tuning fork. A tone generator lets you set the frequency of a tone.

Vibration period Experiment 6

The experimental setup in figure 12 lets you investigate sound vibrations. The **microphone** 'translates' the pressure differences of the sound into an electrical signal. The **oscilloscope** then shows that signal on the screen. This lets you investigate how rapidly the air pressure is changing. There are also programs that let you turn your computer, tablet or smartphone into an oscilloscope.

A set of axes is shown on the oscilloscope screen. Time is presented along the horizontal axis. You can use the knobs on the oscilloscope to set the time scale. This is referred to as selecting the **time base**. In figure 12, the time base is set to 1 ms per division. That means that every square is one millisecond 'wide'.

Four vibrations on the oscilloscope screen take up nine squares altogether. That means that the four vibrations take a total of 9 × 1 = 9 ms, so a single vibration needs 9 : 4 = 2.25 ms. The time required for a single complete vibration is called the **period** (*T*) of the vibration. You say that the period of the vibration of the tuning fork in figure 12 is 2.25 ms.

Period and frequency of a vibration

If you know the period of a vibration, you can calculate its frequency. If the vibration period is 0.1 seconds, there will be 10 vibrations in one second and so the frequency is 10 Hz. If the vibration period is 0.01 seconds, there will be 100 vibrations in one second and so the frequency is 100 Hz. And so forth.

▶ figure 12
This is how you can determine the vibration period of a tuning fork.

You can therefore calculate the frequency using the formula:

$$\text{frequency} = \frac{1}{\text{period}}$$

or in symbols:

$$f = \frac{1}{T}$$

If you use the vibration period T in seconds, you get the frequency f in hertz (Hz).

Worked example
Calculate the frequency of the tuning fork in figure 12.

given $T = 2.25\ \text{ms} = 0.00225\ \text{s}$

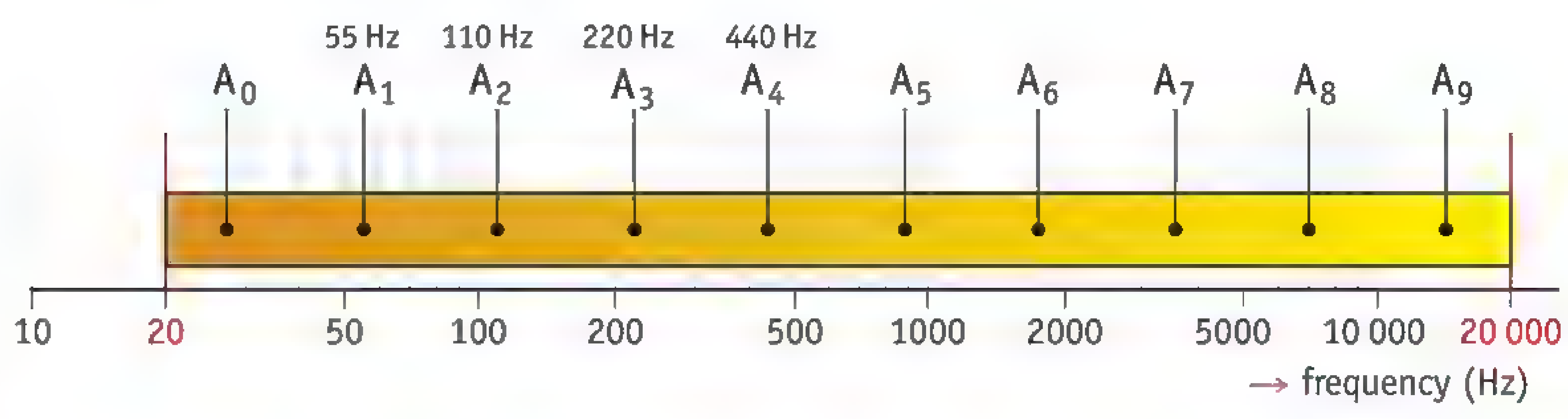
required $f = ?$

working $f = \dfrac{1}{T} = \dfrac{1}{0.00225} \approx 444\ \text{Hz}$

The frequency range of your hearing

If you pluck the A string of a guitar, you hear a fairly low bass note of 110 Hz. This note is known as an A. If you then play a tone of 220 Hz, you hear another A. Although this A is higher, you get the feeling that it is still the same note. We say that this note is an octave higher than the first one. If you then play a 440 Hz tone, you hear another A: one octave higher than the A of 220 Hz and two octaves higher than the A of 110 Hz.

The rule for any note is that if you double the frequency, you get the same note again, but one octave higher. For this reason, frequencies are often represented on a special scale (figure 13). An octave is always represented by the same length on this scale: the distance between 110 Hz and 220 Hz is the same as the distance between 220 Hz and 440 Hz, or between 440 Hz and 880 Hz.



▶ **figure 13**
the frequency range of the human ear

You are not able to hear sounds with very low or very high frequencies. Most people of your age can hear tones between 20 Hz and 20,000 Hz. You say that the tones are within the **frequency range** of your hearing. As you get older, the frequency range of your hearing changes. In particular, you are less able to hear high-pitched tones.

Plus Ultrasound and infrasound

Sound at frequencies above 20,000 Hz is called **ultrasound**. Humans cannot hear these sounds, but some other animals can. Dogs, for example, have no difficulty hearing an ultrasonic whistle with a frequency of 35,000 Hz. Bats and dolphins regularly produce ultrasound noises. Listening to the echoes of these sounds lets them perceive their surroundings. Bats use this method to detect insects (figure 14). Ultrasound is used in hospitals for making scans – sonograms – that can for example let you see the baby in the womb of a pregnant woman.

Sounds with frequencies lower than 20 Hz are known as **infrasound**. This is also sound that you cannot hear, although you can feel it if it is loud enough. Elephants are able to use infrasound to communicate with one another over vast distances.

◀ figure 14
A bat uses sound for hunting.

Exercises

13 Answer the questions below.
- **a** What is meant by 'the frequency of a vibration'?
- **b** What units are used for measuring frequency?
- **c** What does 'the frequency range of your hearing' mean?
- **d** What is the frequency range of hearing for young people with normal hearing?

14 How does the pitch of a guitar string change if the guitarist:
- **a** reduces the tension in the string?
- **b** shortens the effective length of the string by pressing his finger on it?

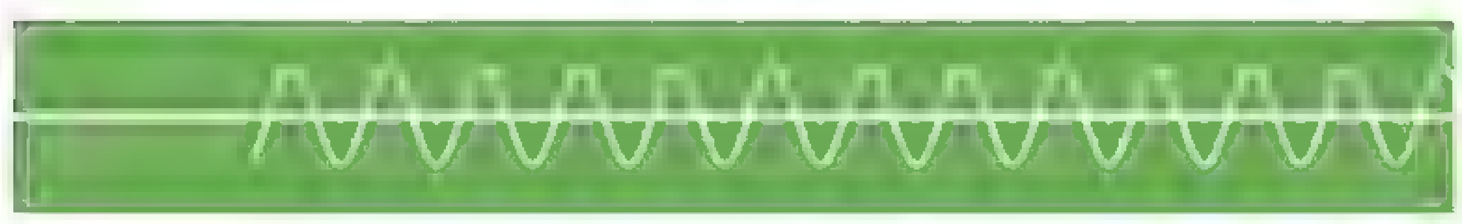
15 Two strings are equally long. One string nevertheless sounds lower than the other.
Give two possible reasons for this.

16 A piano tuner uses a tuning key to tighten or loosen the piano strings. The first string tuned is one that is supposed to give a tone of 440 Hz. Explain what the piano tuner must do if that string gives a tone of 445 Hz.

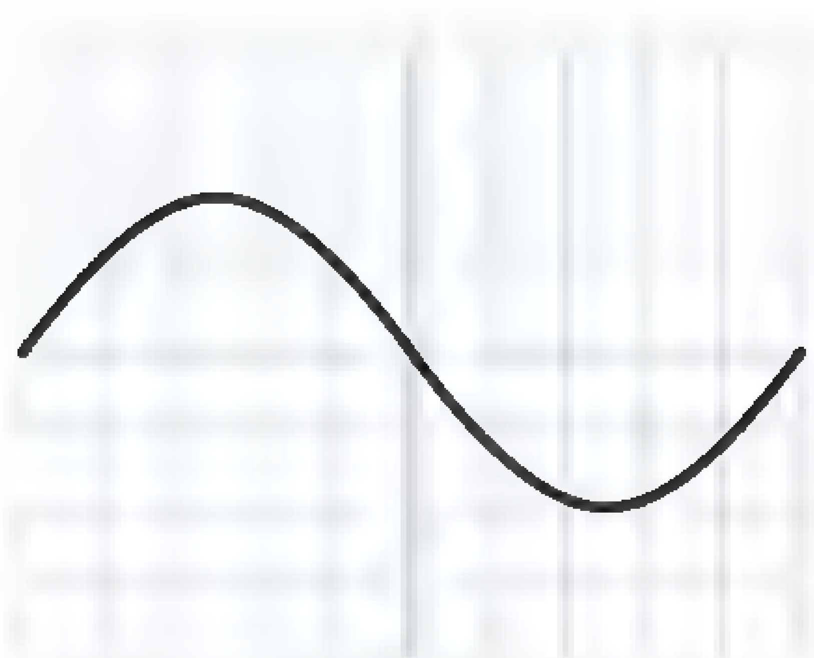
17 The buzzing of a gnat is much higher than the buzzing of a bee. Which insect is moving its wings up and down more times per second? Explain.

18 Karim has attached a needle to a vibrating tuning fork and drawn it along a microscope slide coated with lamp black. Figure 15 shows part of the glass slide drawn full size. The frequency of the tuning fork is 80 Hz.
- a How many vibrations can be seen on the piece of glass?
- b How long did it take to draw this wave trace?
- c How long is the wave trace that you can see in figure 15?
- d Work out the speed at which the tuning fork was drawn across the glass.

▶ figure 15
the wave trace of a tuning fork



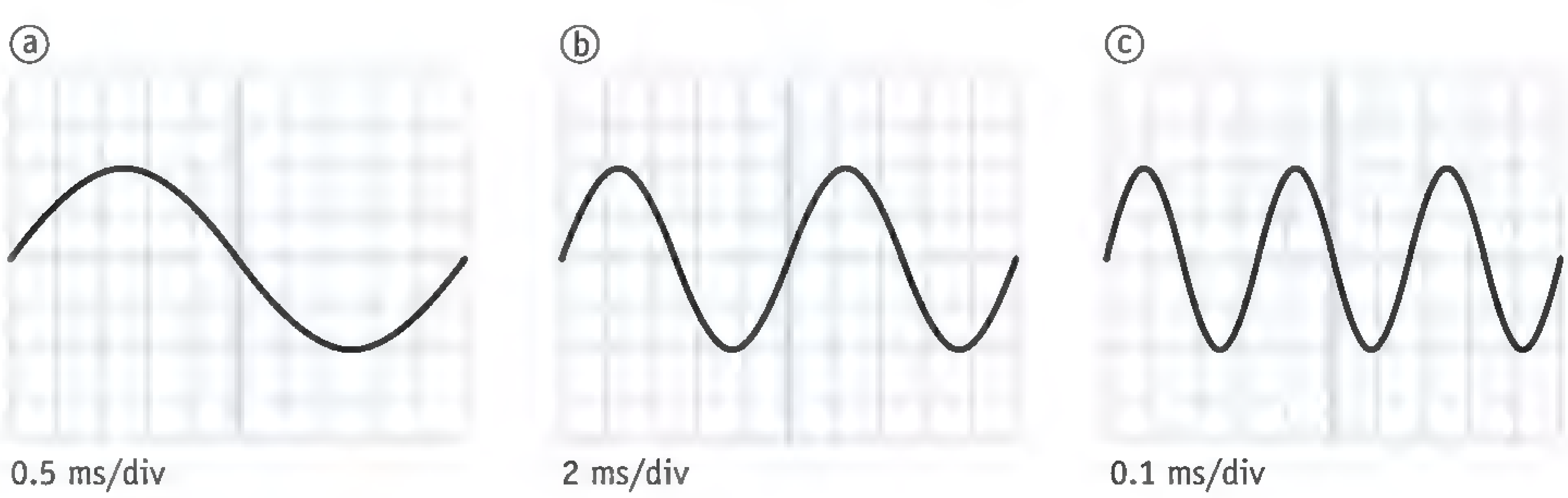
19 Susie is looking at two tones on an oscilloscope, using the same time base. Figure 16 shows you how the oscilloscope represents the first tone. The second tone is one octave higher than the first. Copy the diagram into your exercise book and sketch what the oscilloscope will show for the second tone.

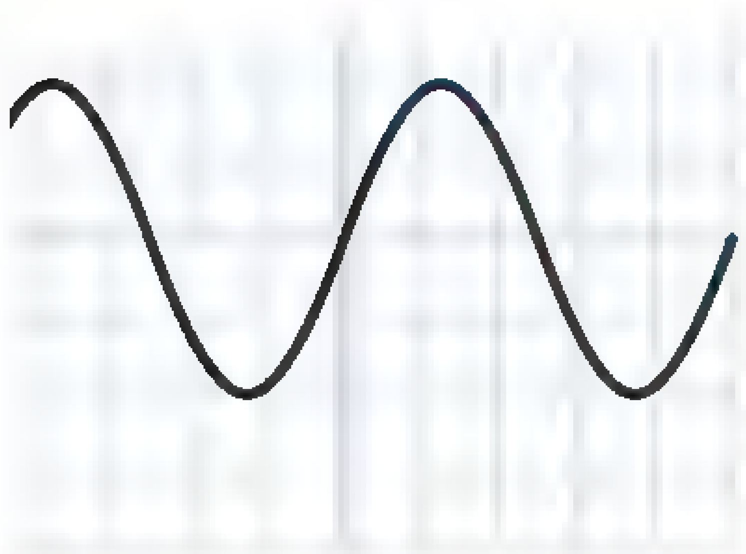


▲ figure 16
What does a tone that is one octave higher look like?

20 See 'Skills 11' at the back of the book.
Three tones (a, b and c) are shown successively on an oscilloscope (see figure 17). The time base is stated for each of the screens.
- a See figure 17a. Copy and complete:
  Each square on the screen represents ...... ms.
  One complete vibration is ...... squares wide.
  The period of the vibration is therefore ...... × ...... ms = ... ms.
- b Determine the vibration periods for tones b and c in the same way.
- c Calculate the frequencies of tones a, b and c.
- d Which oscilloscope picture is showing a high-pitched beep?
- e Which oscilloscope picture is showing a low-pitched hum?

▶ figure 17
three different tones on an oscilloscope screen





▲ figure 18
Billy's oscilloscope picture

SMOKE DETECTORS MORE EFFECTIVE WITH LOW-FREQUENCY ALARM SIGNALS

Researchers at Victoria University in Australia have discovered that it would be better for smoke detectors to emit a lower-pitched sound. According to the researchers, this would allow the detectors to save more lives.
Smoke detectors generally produce a high-frequency sound. That works well if people are awake. However, many people do not hear these high-frequency sounds when they are asleep. The high-frequency sounds generally used only woke up 44% of the test subjects, whereas the low-pitched sound woke up no less than 92% of them.
The researchers show in their study that sounds with frequencies of between 400 and 520 Hz are the most effective. This is particularly clearly the case for people with poor hearing, who specifically can no longer hear the high frequencies.

Source: website of a Dutch association for the hard of hearing

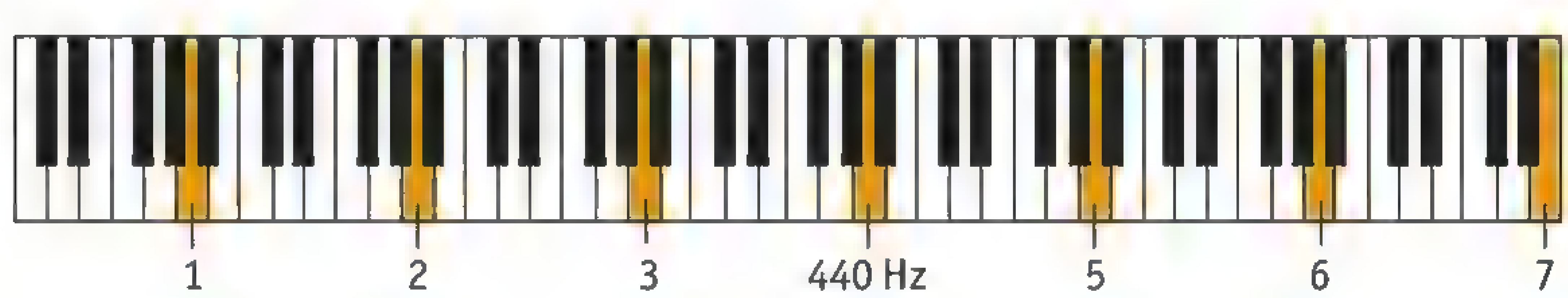
21 Billy is testing a sound system with a program that can produce various test tones. Figure 18 shows how an oscilloscope represents one of the test tones. The time base has been set to 0.2 ms/div.

a Determine the frequency of this test tone.
b How many vibrations will Billy see on the screen if he changes the time base to 1 ms/div?

22 Copy and complete:

a $f = 50$ Hz; $T =$ ...... s
b $f = 440$ Hz; $T =$ ...... ms
c $T = 50$ ms; $f =$ ...... Hz
d $T = 0.25$ ms; $f =$ ...... kHz

23 Figure 19 shows you a piano keyboard. The seven keys that play a note A are numbered 1 to 7. The fourth A (A4) has a frequency of 440 Hz. Write down the frequencies of the other A's that you can play on the piano.



▲ figure 19
the seven A's that you can play on a piano

24 A website gives a news report about smoke detectors (figure 20).

a The report states: "Smoke detectors generally produce a high-frequency sound."
Which frequency range is this sound in?
A Between 0 and 20 Hz
B Between 20 and 2000 Hz
C Between 2000 and 20,000 Hz
D Above 20,000 Hz.

b According to the researchers, sounds at 400 to 520 Hz are 'the most effective'.
What have the researchers investigated so that they can say which sounds are the most effective?

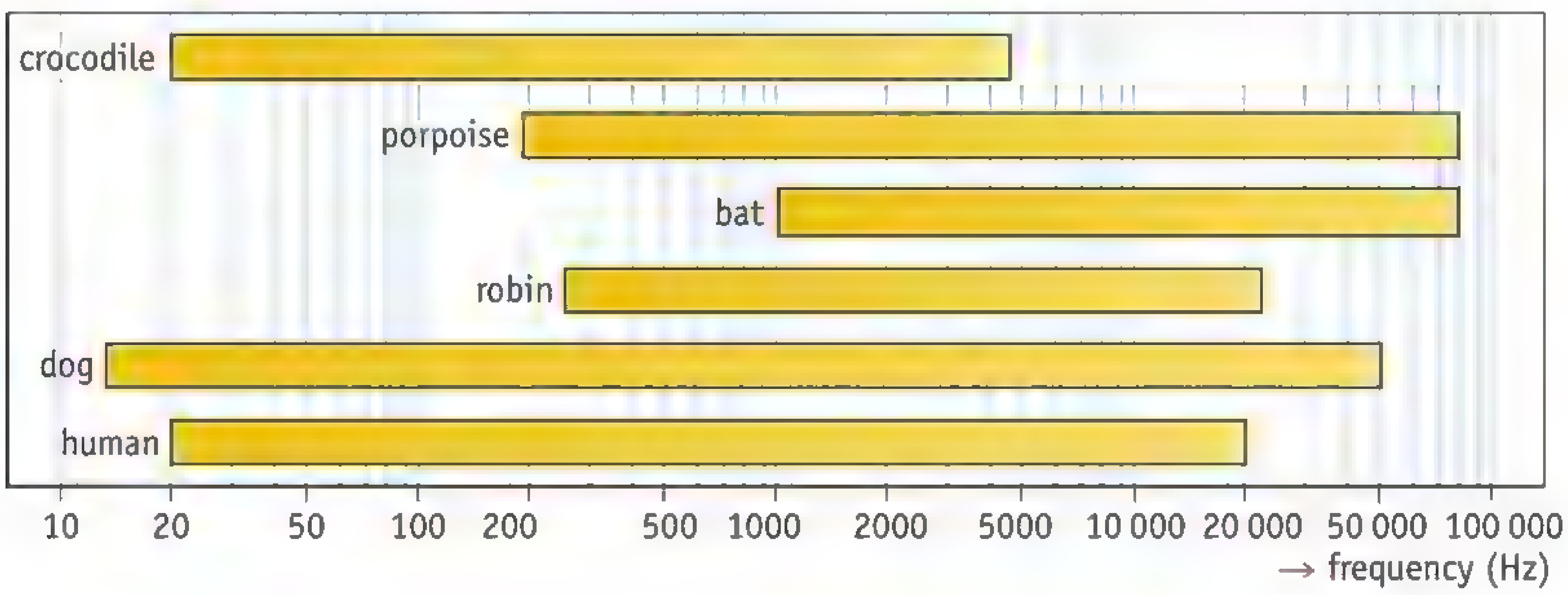
c The researchers believe that smoke detectors should emit a lower-pitched alarm signal.
What two arguments do they give for this?

◀ figure 20
The frequency of an alarm signal can be a matter of life and death.

Plus Ultrasound and infrasound

25 Figure 21 shows the frequency range for humans and a number of other animals.

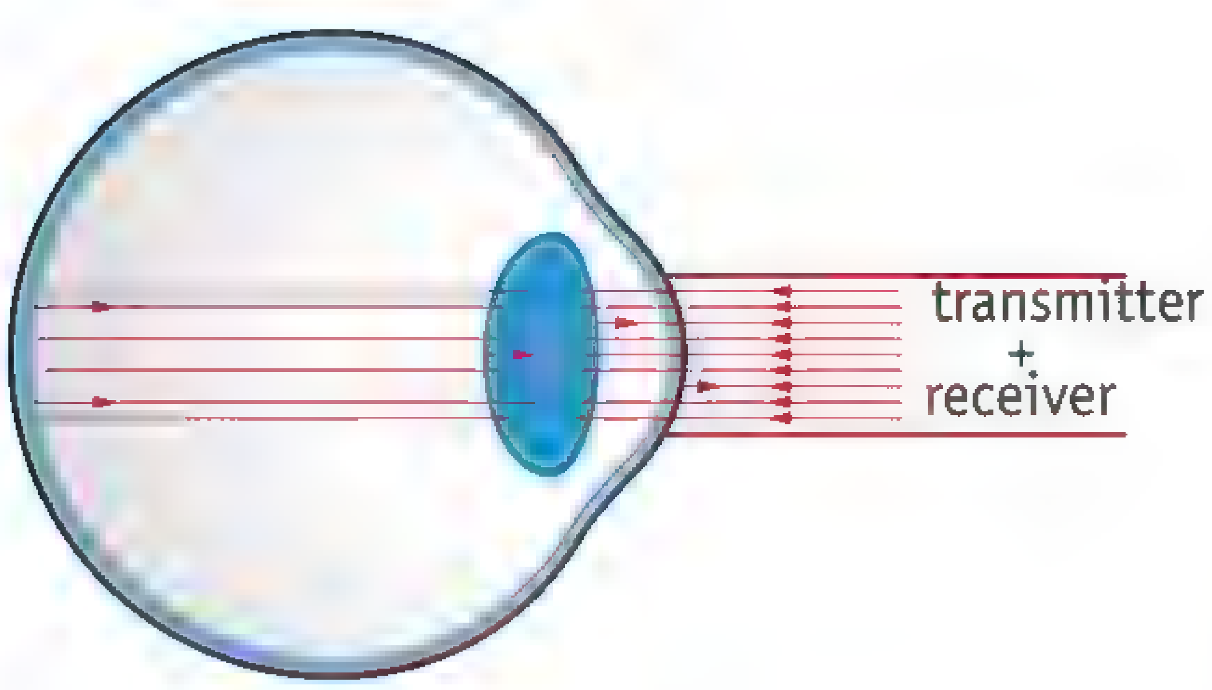
- **a** Which animals can hear the highest tones?
- **b** Which animal can hear the lowest tones?
- **c** A dog whistle makes a sound that a dog can hear but a human cannot. What is the minimum frequency for a dog whistle?
- **d** Are there also tones that a human can hear but a dog cannot? If so, which frequencies are they?



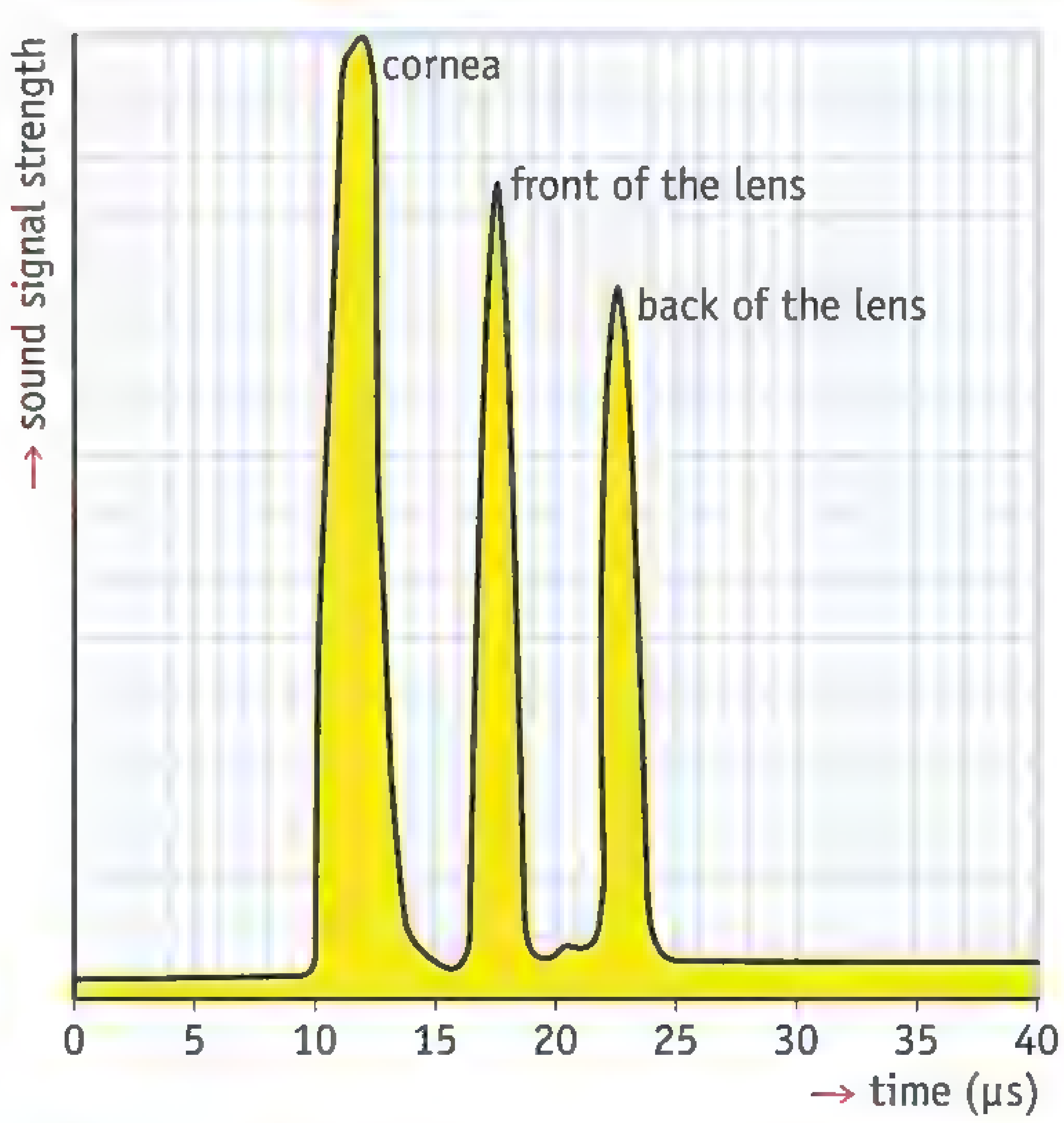
▲ **figure 21**
the frequency range of human hearing and of a number of animals

26 Ultrasound is used to measure the thickness of the lens in an eye. A device that emits ultrasound is placed in front of the eye (see figure 22). The ultrasound is reflected back as an echo by each part of the eye. The echoes can be seen on a screen (figure 23). Figure 23 also gives the times between emitting the sound (at time 0) and receiving the echoes.

- **a** How long does it take before the echo is received from the front of the lens of the eye?
- **b** Sound moves through the eye's lens at a speed of 1500 m/s. Calculate the thickness of the lens.



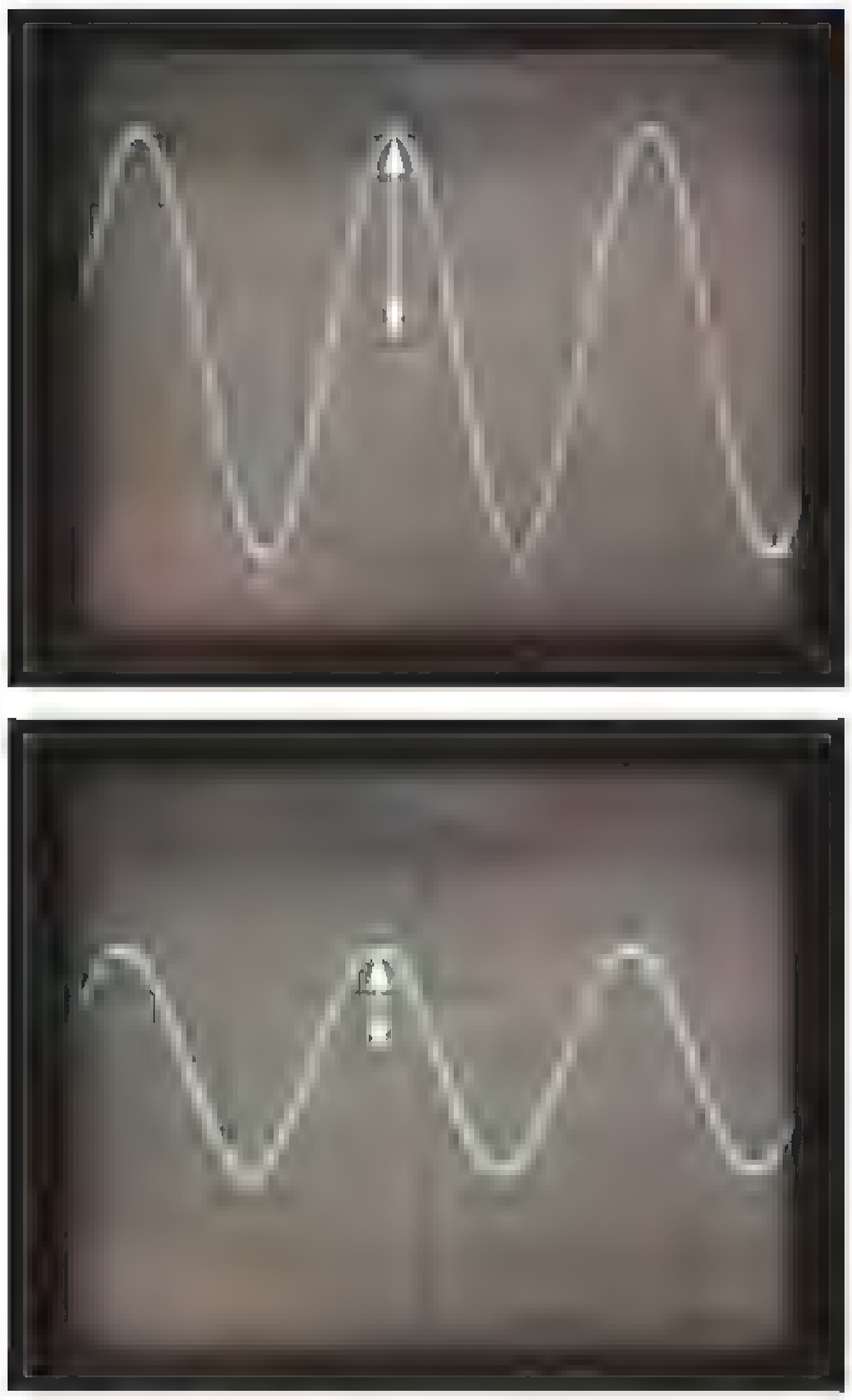
▲ **figure 22**
an ultrasonic measuring device for your eyes



▶ **figure 23**
the signal strengths of the reflected sounds

Nova © Uitgeverij Malmberg

3 Noise levels



▲ figure 24
A loud tone and a quiet one: the amplitude is shown by a double-headed arrow.

Noises can be so loud that you feel them as well as hear them. The sound in a disco or at a pop concert can sometimes be of such a volume that you can literally feel it. The bass notes in particular can resonate in your stomach.

The amplitude of a vibration

When a woofer (bass loudspeaker) is producing the sound of a bass guitar or drum, you can see the cone vibrate. This vibration becomes more vigorous when the volume is turned up. This also makes the pressure differences in the surrounding air greater, which you then perceive as a louder sound.

You can use an oscilloscope with a microphone connected to it for investigating the pressure differences. Have a look at the two oscilloscope screens in figure 24. The top photo shows a loud tone and the bottom photo shows a quiet tone.

Figure 24 shows the **amplitude** of the vibrations: the maximum displacement with respect to the zero reference in the middle. The amplitude increases as the sound intensity becomes greater. When the sound has completely died away, the amplitude is zero.

▼ table 3 noise levels in various situations

example	noise level (dB)
pain threshold: a jet engine at 25 m	140
jet aircraft starting up at 50 m	130
car horn at 2 m	120
concrete drill at 1 m	110
helicopter at 30 m	100
passing train at 25 m	90
passing scooter at 7.5 m	80
vacuum cleaner at 1 m	70
class working	60
residential street in the daytime	50
refrigerator at 1 m	40
pupil whispering	30
rustling leaves	20
pupil breathing	10
limit of detection	0

The decibel scale

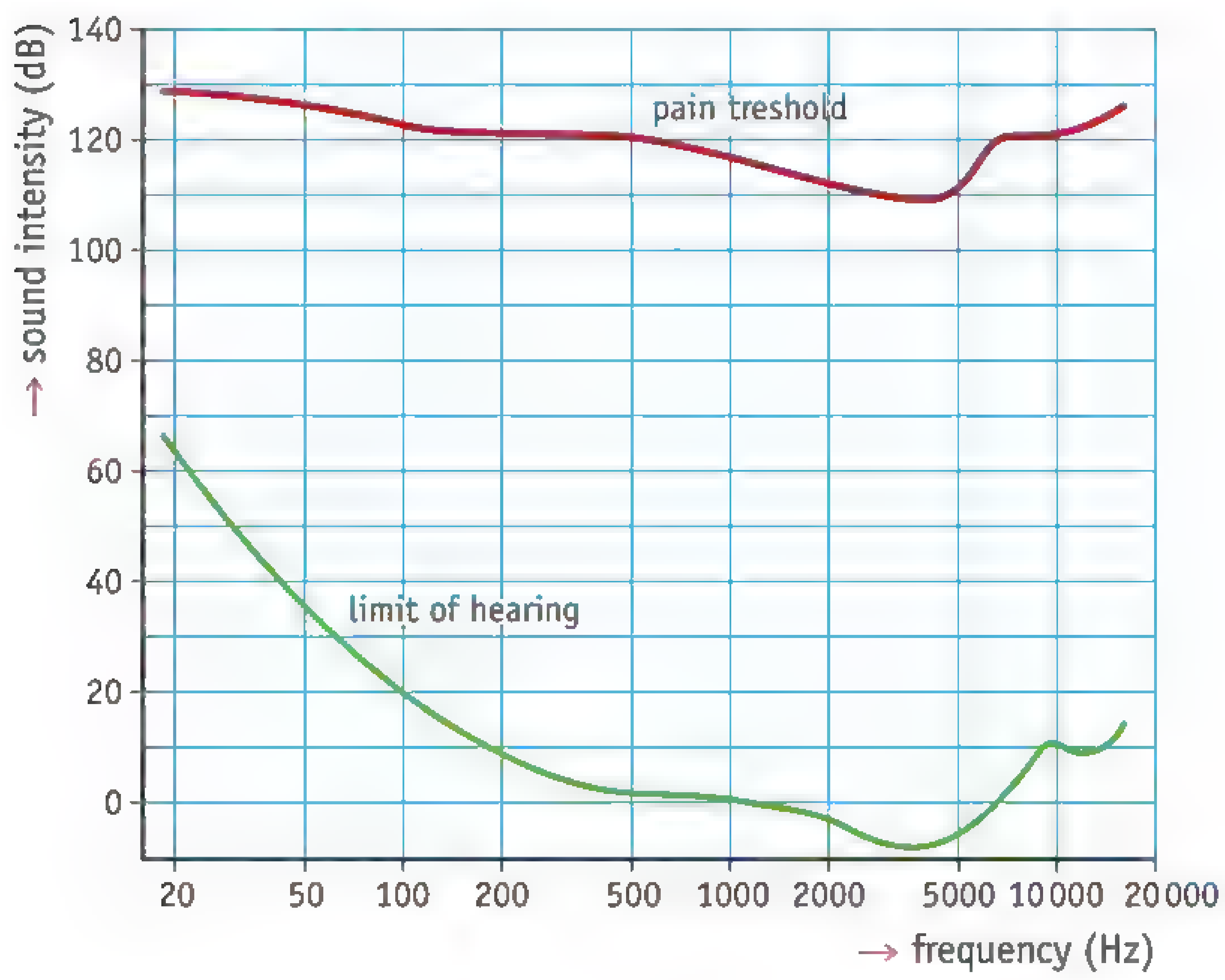
The unit of **sound intensity** is the decibel (dB). Table 3 shows you the sound intensity (sound level) in various situations. A tone with a frequency of 1000 Hz and a sound intensity of 0 dB cannot be heard (or may be just audible if your hearing is very good). So 0 dB does not mean that there is no sound at all. The device that you can use to measure sound intensity is called a sound level meter or a **decibel meter** (figure 25).

◀ figure 25
a decibel meter

You can use a decibel meter to determine how much noise a moped is making. For this measurement the sound level has to be measured at a fixed distance from the exhaust pipe. This is necessary because the sound intensity varies with the distance from the sound source: you will measure a higher sound level twenty centimetres from the exhaust than at eighty centimetres. The closer to the sound source the higher the sound level.

The limit of hearing and the pain threshold

Our ears are not equally sensitive to all frequencies. This can be seen from the graph in figure 26. The **limit of hearing** has been drawn in on this graph. This is the threshold level at which you are just beginning to be able to detect the sound. As you can see, the limit of detection for hearing is greater than 0 dB for many frequencies.



▶ figure 26
the pain threshold and the limit of hearing

The graph shows that your hearing is most sensitive for tones in the middle of your frequency range, around 4000 Hz. Your hearing is nowhere near as acute for very high and very low tones. This makes tones in those ranges seem less loud than they really are. The **pain threshold** – the sound intensity at which your ears start to hurt – is not the same for all frequencies either.

Because your ears are not equally sensitive at all frequencies, most decibel meters have an **A filter**. This adds a profile or contour to the meter's response, giving a lower weighting to very high and low frequencies. This allows the meter to approximate the sound intensities as we perceive them with our ears. If you use the A contour filter, you have to state the sound level in dB(A).

There is virtually no difference between the dB scale and the dB(A) scale at frequencies from 500 to 10,000 Hz. These are the frequencies at which your ears are most sensitive. These are also the frequencies that are most important for being able to understand speech. But for low and very high tones, the sound level in dB(A) is less than the sound level in dB. Measurements that are made to determine noise nuisance always use the dB(A) scale.

Calculations with decibels

If you double the number of sound sources, the sound does not seem twice as loud. You can see that if you measure the sound intensity in your school's music room. When one pupil is singing, the sound intensity will be somewhere around 55 dB. But if 32 pupils are all singing at once, the (average) sound intensity will not be 32 times as high. You 'only' measure an average sound intensity of 70 dB.

The decibel scale is designed to match the way humans perceive sound. If the number of sound sources is doubled the total power emitted goes up by a factor of two. But your perception is that this only gives a modest increase in the quantity of noise. On the decibel scale this is a step of just 3 dB.

The magnitude of the sound level in decibels can therefore be worked out using the following calculation rule:

> If the number of sound sources becomes twice as great the sound level increases by 3 dB.

You can, however, only use this rule if all the sound sources are (roughly) equally loud and (roughly) equally far away.

Worked example
The sound level is measured ten metres away from a concert stage (figure 27). If just one violin is playing, the sound intensity is 70 dB. What sound intensity would be measured if a group of eight violins were playing?

The number of decibels is:
- for a single violinist: 70 dB;
- for two violinists: 70 + 3 = 73 dB (from 1 to 2 is the first doubling);
- for four violinists: 73 + 3 = 76 dB (from 2 to 4 is the second doubling);
- for eight violinists: 76 + 3 = 79 dB (from 4 to 8 is the third doubling).

If eight violinists are playing, you therefore measure a sound level of roughly 79 dB.


1 violinist: 70 dB


2 violinists: 73 dB


4 violinists: 76 dB


8 violinists: 79 dB

▲ **figure 27**
The sound intensity increases in steps of 3 dB.

Plus Sound intensity and distance

Experts distinguish between 'point sources' and 'linear sources' of sound. If the noise is coming from a single source – a single car on a quiet country road, for example – then it is a point source. The perceived sound level depends on how far away from the sound source you are. Experiments and calculations show that:

doubling the distance between yourself and a point sound source reduces the sound intensity (that you perceive) by 6 dB.

▼ figure 28
a linear sound source

However, a busy main road creates a 'ribbon' of noise (figure 28). In this case the road is a linear (straight line) sound source. How far you are away from the road is then defined as the shortest distance, i.e. measured at right angles to the road. The rule for the noise from a linear sound source is that:

doubling the distance between yourself and a linear sound source reduces the sound intensity (that you perceive) by 3 dB.

Increasing the distance is therefore far more effective for a point sound source (6 dB reduction on doubling the distance) than it is for a linear sound source (3 dB reduction).

Exercises

27 Answer the questions below.
- **a** What units do we use for sound levels?
- **b** What is the name of the device that you can use to measure sound levels?
- **c** What is the threshold of hearing?
- **d** For which tones is the threshold of hearing greater than 0 dB?

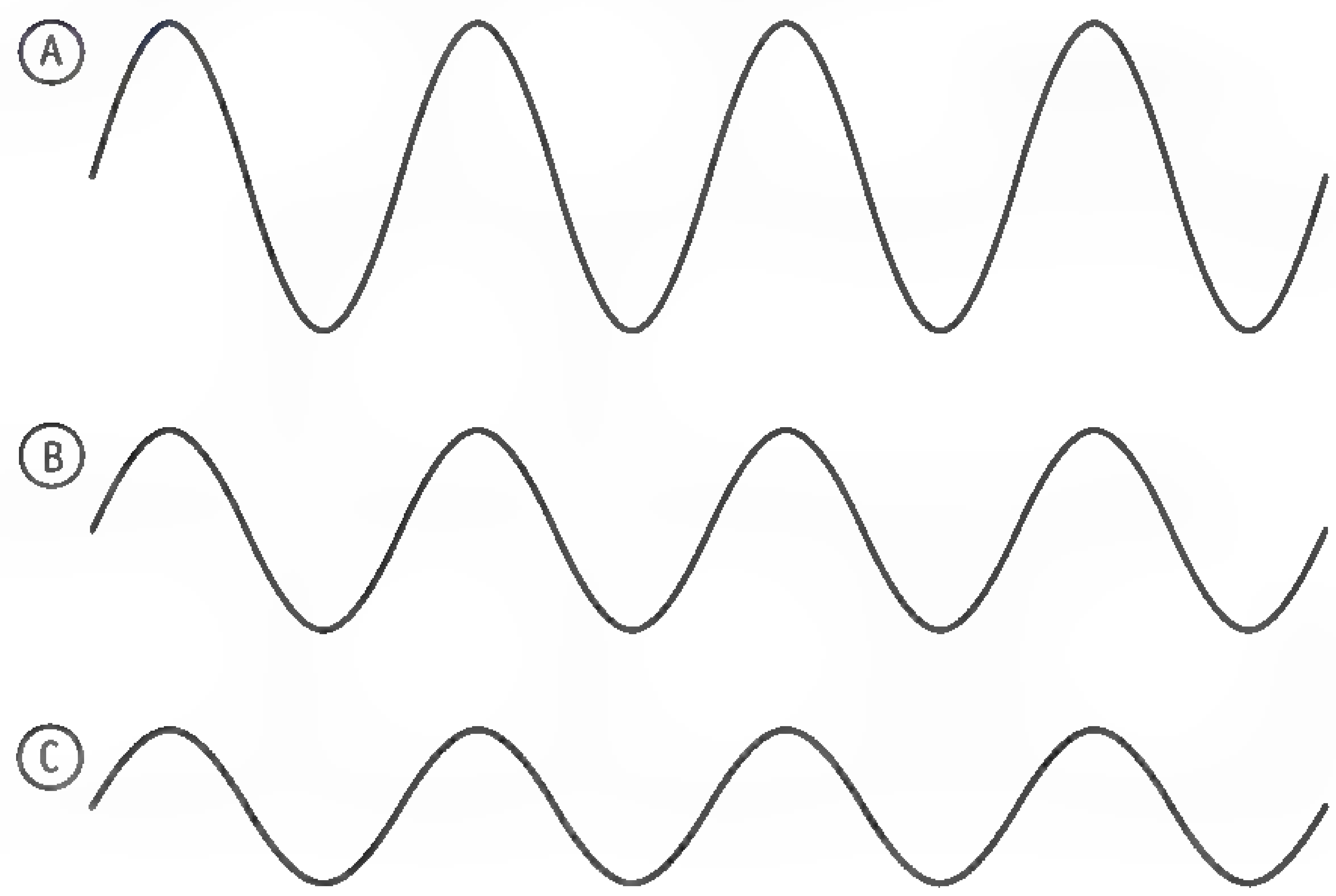
28 The dB(A) scale is often used instead of the dB scale.
- **a** What is the name of the filter that is used for this?
- **b** Which tones do the contours of this filter then weaken?
- **c** Why are these tones weakened?
- **d** When is the dB(A) scale used?

29 Dimitri strikes a tuning fork. He hears a tone that gradually attenuates (fades away).
- **a** Does the frequency of the sound vibration change as the tone becomes quieter? If so, how does it change?
- **b** Does the amplitude of the sound vibration change as the tone becomes quieter? If so, how does it change?

30 Caitlin strikes a tuning fork. She then draws a stylus that has been attached to the tuning fork across a sheet of glass that has been coated with lamp black. Figure 29 shows you three sections of the sound trace that it leaves, magnified 10×.

a What is the amplitude at A? At B? At C?

b The section of the wave trace at A was produced earlier than the section of the wave trace at B. How can you see that?



▶ **figure 29**
three sections of Caitlin's wave trace

31 A police officer is checking whether the engine of a moped is making too much noise. When doing this, she holds the decibel meter 50 cm from the exhaust.

a Explain why the sound intensity always has to be measured at a fixed distance from the sound source.

b What goes wrong if the distance between the decibel meter and the exhaust is greater than 50 cm?

c What goes wrong if the distance is less than 50 cm?

32 Refer to the graph in figure 26.

a A tone has an intensity of 20 dB and its frequency is 50 Hz. Can you hear that tone?

b A tone has an intensity of 20 dB and its frequency is 5000 Hz. Can you hear that tone?

c What is the minimum sound level for a tone of 100 Hz if you are to be able to hear it?

d What is the minimum sound level for a tone of 10,000 Hz if you are to be able to hear it?

33 Carl leaves the engine of his moped idling. The sound level 5 m away from his moped is 74 dB.

a Carl is joined by Rob, Hal and John. All four of them leave their scooters idling equally fast.
What is the sound level now, 5 m away from the four scooters?

b John and Hal drive off. What is the sound level now, 5 m away from the two remaining scooters?

34 The noise level in a football stadium is measured at the centre of the pitch. When 1000 people are cheering, the decibel meter registers 80 dB. Give an estimate of the approximate noise level if 100,000 people were cheering. Explain how you got your answer.

35 Read the newspaper article in figure 30. Suppose that the town council were to adopt the limit of 54 dB requested by the residents.

a Calculate roughly how many people would then be allowed to be out on the Waalkade for the evening on the quayside.

b Explain why it is impossible to give an exact number.

The bustle of the people alone produces a noise level of 75 dB

By our reporter

NIJMEGEN – Noise levels were once again measured on the Waalkade on Thursday evening because an estimated twenty thousand people were out and about on the quayside for the Four-Day Walk event.
Strikingly, the hustle and bustle of the people alone – in other words with no music – created noise levels of 75 decibels (dB).
According to Ruud Schilder of the town council's Economic Affairs department, that fact proves that sticking to the limit of 50 to 55 dB is not feasible during the event.
Last week, a group of Waalkade residents took out an injunction in an attempt to make that guideline limit mandatory.

Source: De Gelderlander

▶ figure 30
noise on the Waalkade

***36** A device produces a buzzing noise with a frequency of 100 Hz. At a distance of 10 m, the intensity of the buzz is 0 dB.

a How many of these devices would have to be running at the same time before you could hear the buzz from 10 m away?

b If the frequency of the noise becomes higher you are then able to hear it.
What frequencies can you just hear if the sound level is 0 dB?

c At a distance of 40 m, sixteen of these devices together give a sound intensity of 0 dB.
What is the sound level from a single device at a distance of 40 m?

Plus Sound intensity and distance

37 A moped goes past Hal at a distance of 15 m. The sound level where Hal is standing is 78 dB. After thirty seconds or so, the moped is 480 m away from Hal.

a Is a moped a point source or a linear source? Explain.
b Copy table 4 into your exercise book and fill in the missing values.
c What sound level will Hal observe after 30 seconds?

▼ **table 4** the relationship between sound level and distance for a point source of noise

distance (m)	noise level (dB)
15	78
30	
60	
	60
	54
480	

Situation 1
A road worker is using a jackhammer on a motorway that has been closed to traffic. Measurements 25 metres away from the road worker show that the drill is registering an average of 75 dB.

Situation 2, three months later
The motorway has now been opened again and there is heavy traffic during the morning rush hour. Measurements 25 metres from the road show that the traffic is producing an average of 60 dB.

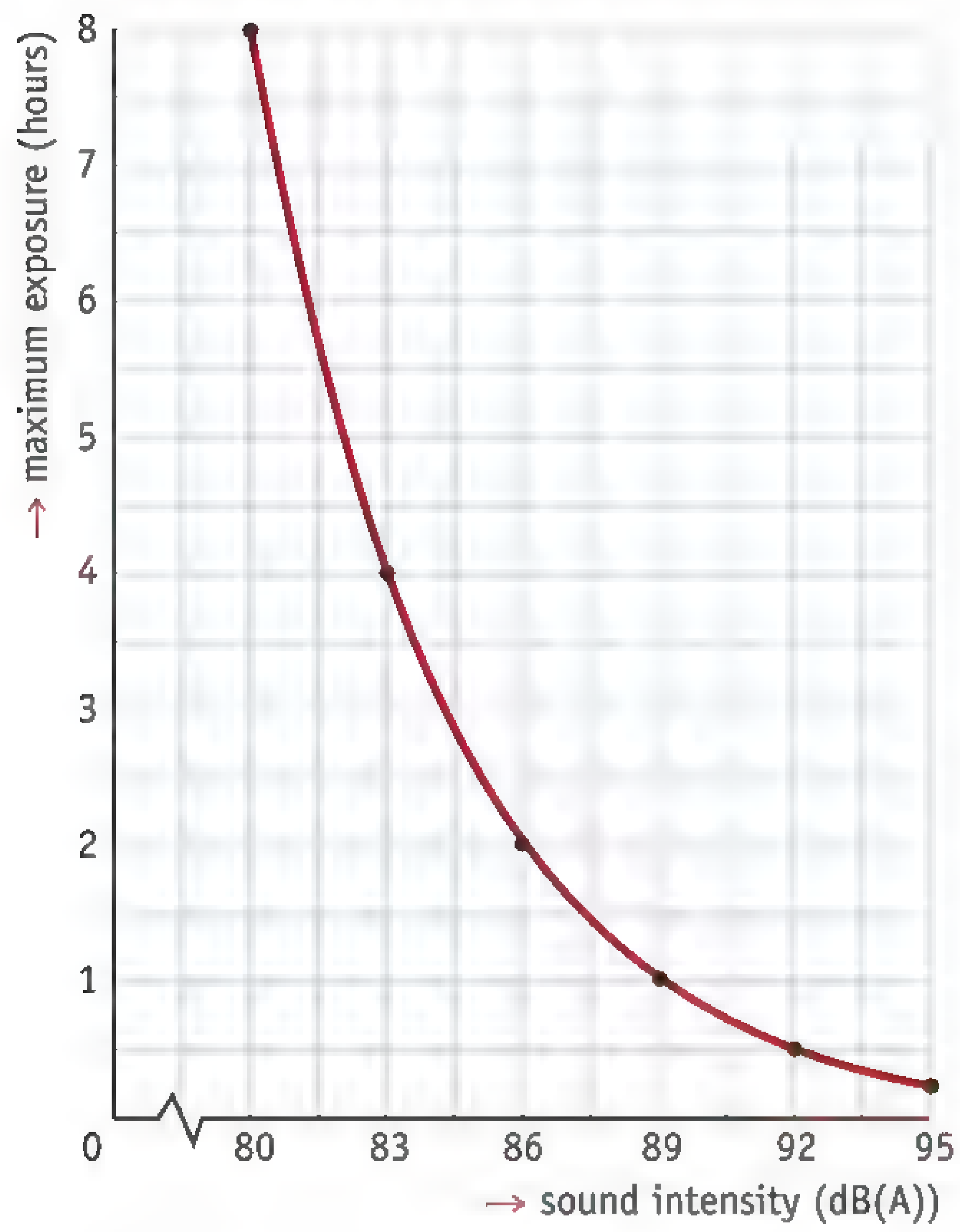
***38** Compare the two following situations:

a There is a house 200 m from the motorway at the point where the road worker had been using his jackhammer.
Calculate the sound level at the house in:
- situation 1.
- situation 2.

b The boundary of a residential district is 1200 m from the motorway. Which can the people living there hear better: the jackhammer or the traffic?
c Explain how you got to your answer for question b.
d What is the shape of the zone where the sound level is greater than 55 dB in:
- situation 1?
- situation 2?

4 Combating noise nuisance

Noise can be extremely irritating. Think of the sound of a dripping tap or a fork screeching across a plate. Noise nuisance from neighbours is high up the list of things that annoy people most in the Netherlands. Loud noises are also capable of damaging your hearing permanently. All very good reasons for combating unnecessary noise.



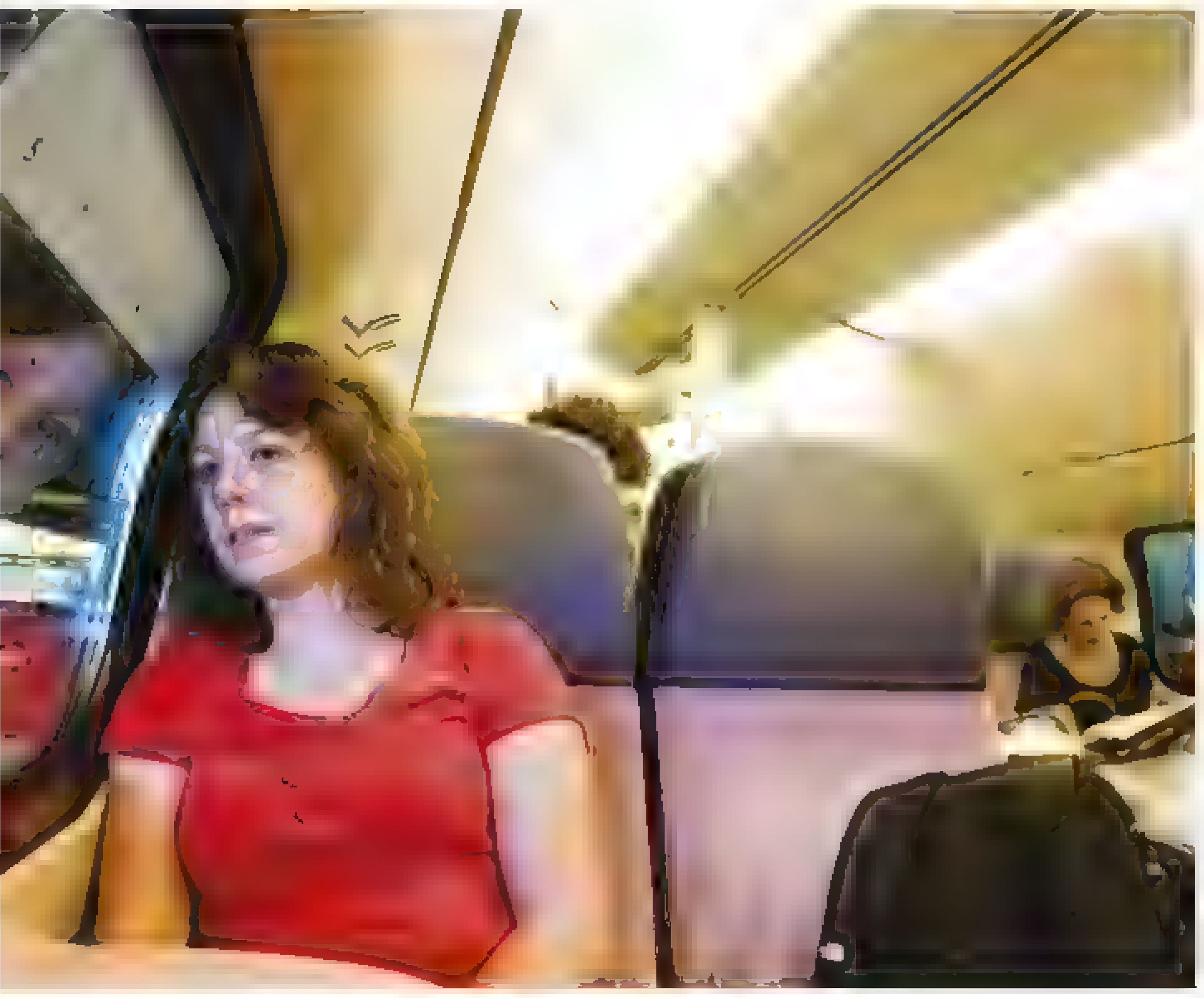
▲ figure 31
The louder the noise, the shorter the time you are allowed to be exposed to it.

Harmful sound intensities

Loud noises are bad for your hearing. If the sound levels are up at the pain threshold, your hearing can be damaged almost immediately. Lengthy exposure to noise at 80 to 90 dB can be enough to damage your hearing. Many people underestimate the risk, because you do not notice at first that your hearing is deteriorating.

Whether or not noise is harmful for your hearing depends on more than just the intensity. The length of time that you are exposed to the noise plays a part too. Figure 31 shows you the maximum times for which an employee may be exposed to noise. For noise at 80 dB(A), the figure is eight hours; for noise at 83 dB(A) it is four hours; for noise at 86 dB(A) it is two hours, and so forth.

Once that maximum time has elapsed, you must give your hearing a chance to recover again, otherwise you will be risking permanent hearing damage. It can take years before the damage becomes noticeable. By the time you are becoming hard of hearing, you are already too late: the damage can then no longer be reversed.

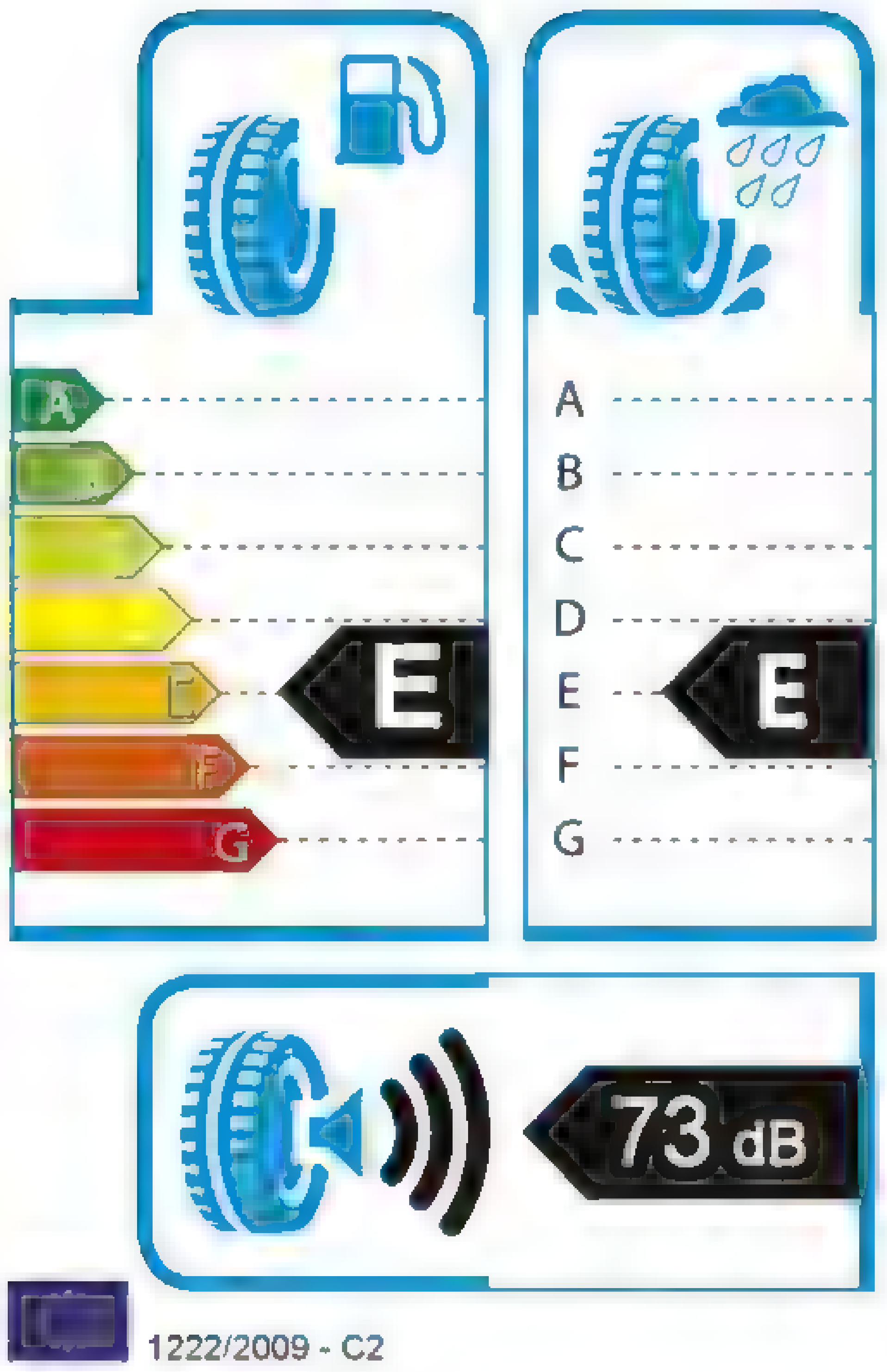


▲ figure 32
traveling in a 'silent' carriage

Noise nuisance

Noise that is not harmful can nevertheless be a nuisance. Some people are more affected by particular nuisance sounds than others. Many people get irritated by traffic noise and excessively noisy neighbours.

Whether or not you feel a noise is a nuisance often depends on the situation. A party at the neighbours is not necessarily a problem at all, until you want to go to sleep and realise that the music is in fact pretty loud. Many people are not bothered if others in their train carriage want to talk, but a 'silent' carriage can be very pleasant for people who want to work quietly (figure 32).



▲ figure 33
Tyres with two stripes comply with the new regulations; tyres with three stripes do not.

However, noise nuisance that stops people from sleeping properly is more than just an annoyance. Lack of sleep causes irritability, poor concentration and fatigue; over the course of time a lack of sleep can have a negative effect on your health.

Noise abatement measures

A car driving along a road produces quite a bit of noise. There is noise from the engine propelling the vehicle, from the wheels moving over the road surface and from the air flowing past the car. You can also easily hear the brakes when the motorist presses the brake pedal.

Various ways have been thought up to reduce traffic noise nuisance. Experts divide these measures into three categories: at the source, between source and receiver, and at the receiver.

At the source
These are measures that lead to the source – the traffic – producing less noise. This might, for instance, include surfacing motorways with special low-noise asphalt. Stricter rules are also coming into force about the amount of noise car tyres may make (figure 33).

Between the source and the receiver
These are measures in the area between the road and a residential area, such as **noise barriers** (e.g. embankments and screens). Commercial premises are also often planned alongside motorways, so that they can screen off the residential districts behind them.

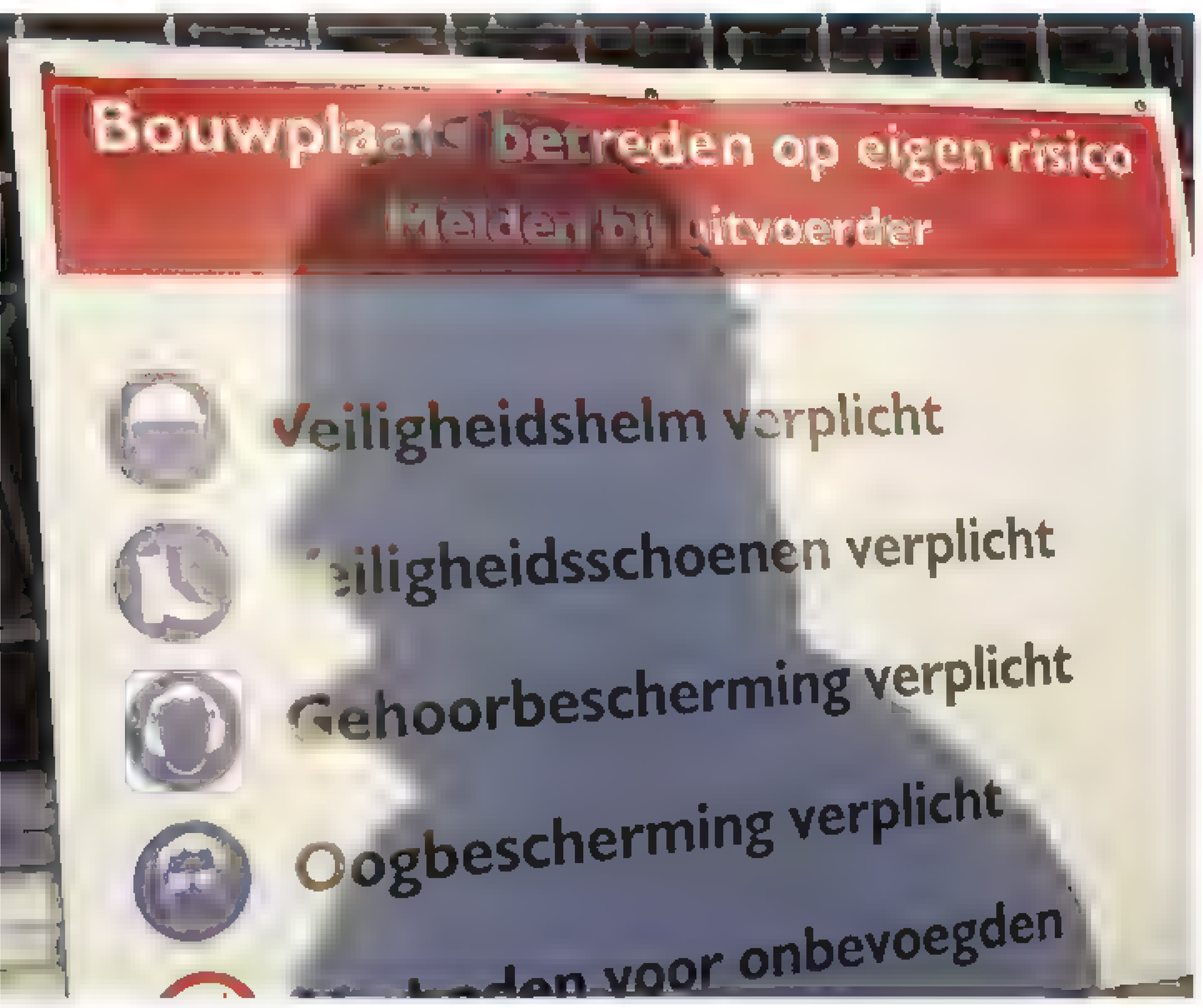
At the receiver
These are measures that are taken in the residential areas. For instance houses that are close to a motorway are even more thoroughly insulated against noise. Much less noise then gets inside the houses.

Absorbing or reflecting sound

A thick embankment of earth beside a motorway can dampen traffic noise considerably. The sound is **absorbed** by this type of barrier: the sound vibrations penetrate the embankment to a certain degree, but fade out before getting through to the other side. Materials that are intended to absorb sound are soft and have irregular surfaces.

If there is not enough room for an embankment as a barrier, a screen is often placed alongside the motorway. A screen such as this **reflects** the sound, so that it does not reach the houses and flats by the motorway (figure 34). Materials that are intended to reflect sound are hard and have smooth surfaces.

▲ figure 34
a noise screen



▲ figure 35
Ear protection is mandatory here.

Sound insulation

Noise pollution can often be combated by **sound insulation.** This is often done using insulation material such as glass wool, which absorbs sound very well. The insulation can be applied at the source of the noise or at the receiver. Both methods are used in practice.

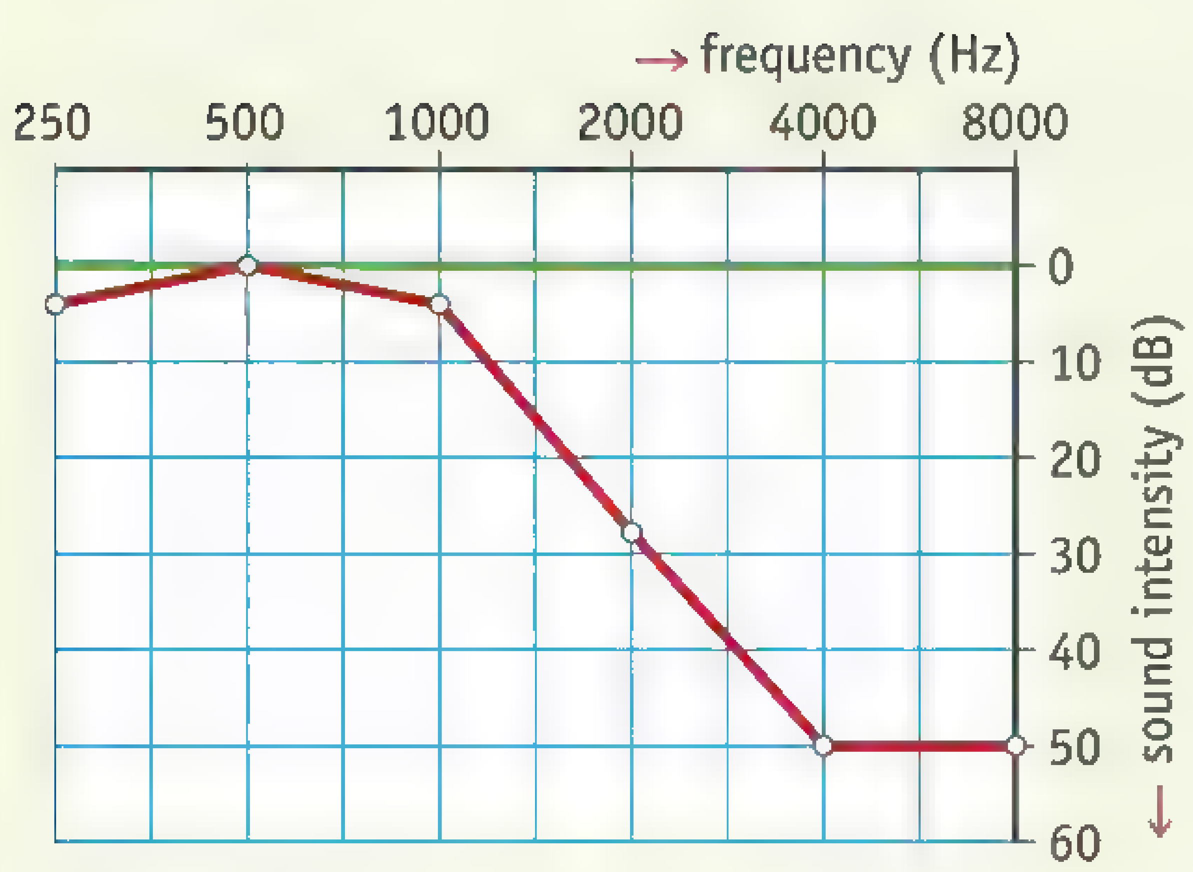
You can insulate a noisy machine by building a properly enclosed casing around it, with a good thick layer of insulating material. The noise vibrations are attenuated substantially by an insulating layer like this. Noisy machines are often mounted on rubber feet. The rubber damps the vibrations so that they are not transmitted to the floor.

Sound insulation can also be applied at the receiver. For example, employees must wear **earmuffs** or **earplugs** if the noise levels at their place of work exceed 85 dB(A) (figure 35). This considerably reduces the amount of noise reaching their ears.

Plus Audiograms

If a doctor suspects that your hearing is damaged he can have your hearing tested by an audiologist. The result of the test is recorded in an **audiogram:** a graph showing you what your hearing is like, compared to normal hearing. In general, a separate audiogram is made for each ear.

The test involves getting you to listen to a tone (e.g. 250 Hz) through headphones. The tone is inaudibly quiet at first, but then gets louder. You give a signal to the audiologist when you can hear the tone. This determines your threshold of hearing for a 250 Hz tone, i.e. the sound level at which you can just hear the tone. The same is then done for a number of other frequencies.



▲ figure 36
This audiogram shows a hearing loss of up to 50 dB for the higher tones.

Figure 36 shows you an audiogram that has been produced using a series of such measurements. The graph shows you the difference between your threshold of hearing and that of someone with normal hearing. If the graph follows the green zero line, then you have perfectly normal hearing. Small deviations from the zero line are very common and do not mean there is any problem, but the differences are larger if your hearing is damaged. The audiogram in figure 36 is for someone who does not hear high tones well. For those tones, the discrepancy is up to 50 dB.

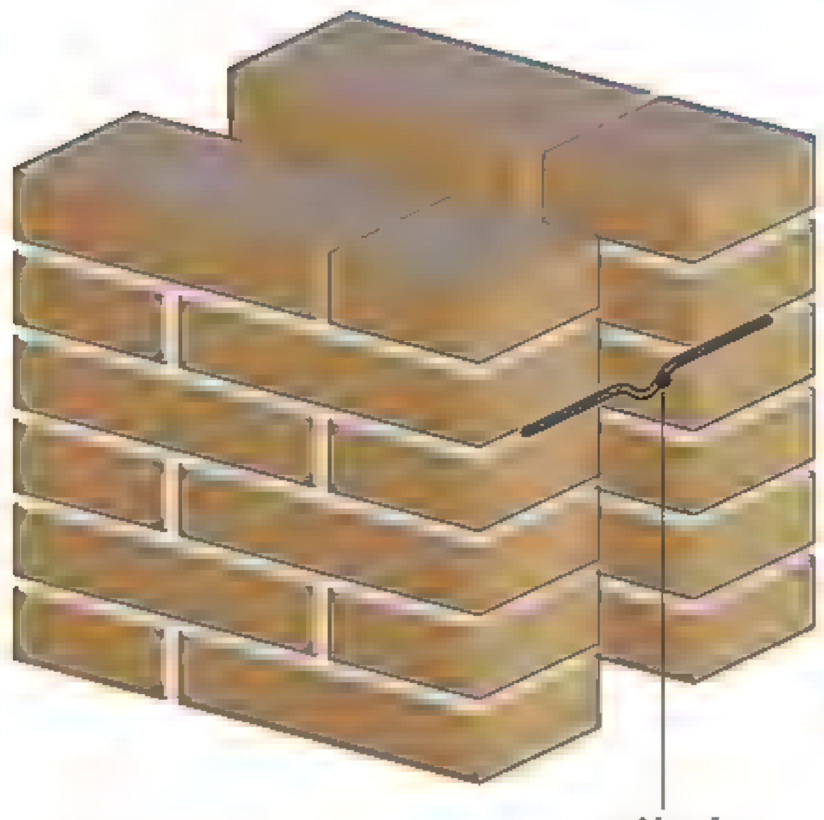
Exercises

39 Noise can be a nuisance and it can be damaging.
- **a** When is noise damaging?
- **b** Give an example of damaging noise.
- **c** When is noise a nuisance?
- **d** Give an example of a nuisance noise.

40 The traffic on a busy road can make a lot of noise.
State one way of combating noise nuisance:
- **a** at the source.
- **b** between the source and the receiver.
- **c** at the receiver.

41 Callum is complaining about the noise Mel is making. Mel can respond to this in various ways (see figure 37).
For each response, state whether the measure is being taken at the source, between the source and the receiver, or at the receiver.

▲ figure 37
Could you turn it down a little?



▲ figure 38
cavity wall with wall ties

42 Frank lives on the fifth floor of a block of flats. He is a pianist and he needs to practice several hours a day. When he is playing his piano, the low notes can clearly be heard on the first floor of the apartment block.
- **a** By what route (or routes) does the sound of the piano get down to the first floor?
- **b** Frank's downstairs neighbours asked him to put thick pieces of rubber underneath the feet of his piano. Why are the downstairs neighbours now less bothered by Frank's piano playing?
- **c** Frank insulates the room that the piano is in. Why is it better not to have the insulation attached to the wall?

43 A cavity wall consists of an internal wall and an exterior wall. These two walls are often connected together with steel rods called wall ties (figure 38). A cavity wall provides better noise insulation if ties are not used.
Explain why.

44 If you turn the volume of the music on your mobile phone or MP3 player up to its maximum, the sound level in your ears can easily reach 95 dB(A). Use figure 31 to help answer the questions below.
- **a** Is a sound intensity of 95 dB(A) bad for your ears? Explain.
- **b** How long can you listen to music at 95 dB(A) reasonably safely?
- **c** Jake says that he has the earphones of his phone in almost all day long.
  What is a safe sound level for someone who listens to that much music?
- **d** Traffic experts say that it is better for you not to listen to music in the traffic.
  What is their reason for saying that?

***45** Read the article in figure 39.
- **a** What does the 'noise shadow' mean?
- **b** Do the sums to show that a noise is 32× quieter if the level is reduced by 15 dB.
- **c** How many times quieter does a noise sound if the level goes down by 5 dB? Make an estimate.

▶ figure 39
noise screens

Noise barriers offer less protection

Noise screens next to motorways provide much less protection against noise nuisance than was thought. In practice, the wind can 'lift' the traffic noise over the screens. This means that the 'sound shadow' behind the barriers is much smaller than has been assumed. A screen that was supposed to reduce levels by fifteen decibels actually only did so by five decibels. Research has shown that it is better to construct noise barriers that comprise an earth embankment with a rounded top.

Source: De Ster

Plus Audiograms

46 You need worksheet 7-1 for this exercise.
An audiologist has tested Jack and Billy's hearing. Table 5 shows you the results of the investigations.

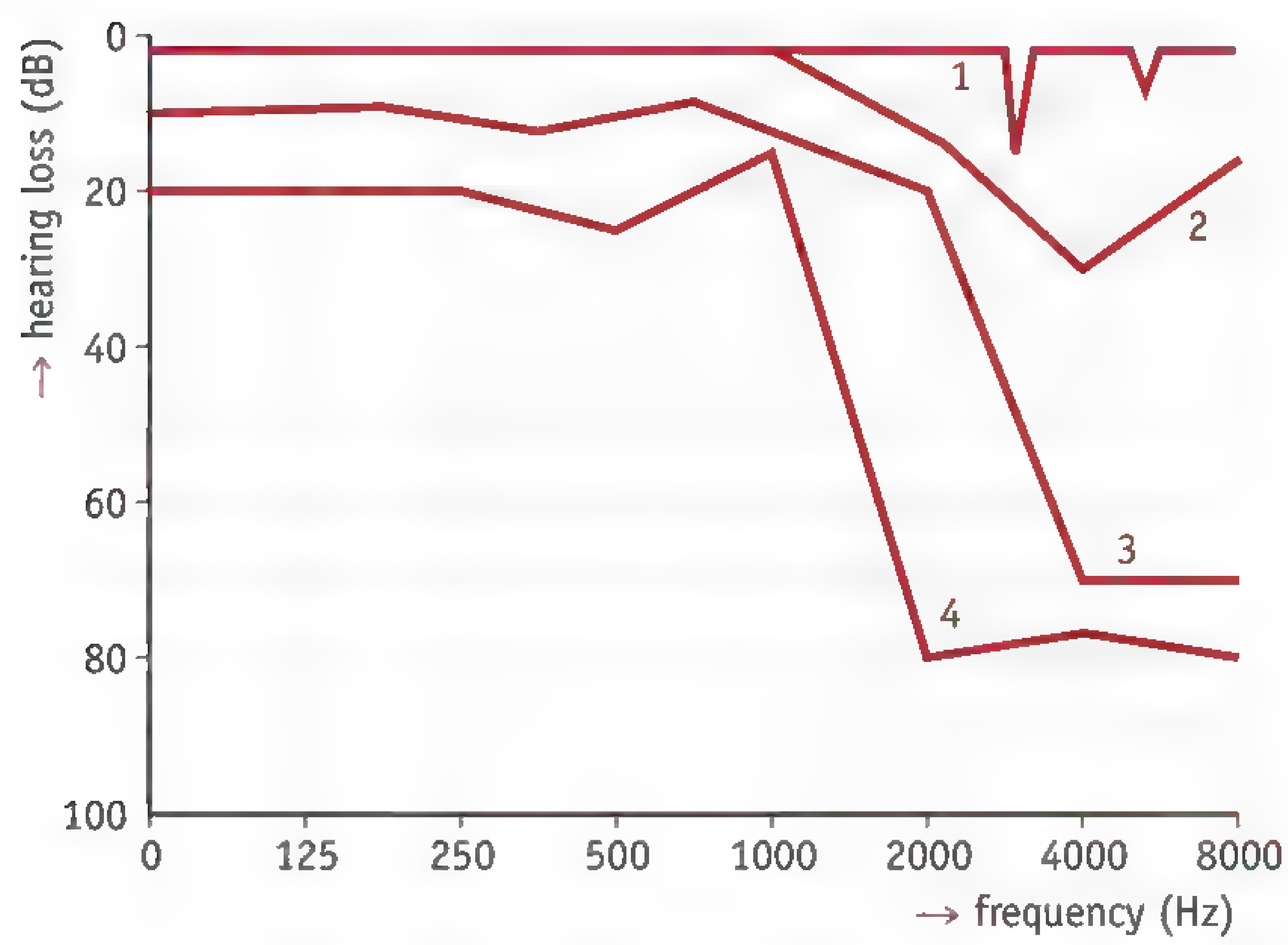
- **a** Draw Jack's audiogram in on figure a on the worksheet.
- **b** Draw Billy's audiogram in on figure b on the worksheet.
- **c** Which of the two boys' audiograms is not normal?
- **d** Which tones can he hear less well?

▼ **table 5** the results of two hearing tests

frequency (Hz)	Jack: deviation in dB(A)	Billy: deviation in dB(A)
250	2	62
500	0	48
1000	0	25
2000	–2	7
4000	–2	3
8000	0	2

***47** Noise-induced hearing loss occurs when your ears have been exposed to noise for too long. Figure 40 shows audiograms of people in various stages of noise-induced deafness.

- **a** What does hearing damage in stage 3 or 4 mean for listening to music?
- **b** People with hearing damage in stage 3 receive a hearing aid.
  Sketch a graph showing how the hearing aid should amplify sound.
  Plot the amplification (in dB) against the frequency (in Hz).



▶ **figure 40**
audiograms of people in various stages of noise-induced hearing loss

Experiments

Experiment 1 The tuning fork 15 min

Introduction
Noise arises when objects vibrate, such as a tuning fork or a loudspeaker. The movement of the sound source also makes the surrounding air vibrate. That allows the sound to reach your ears.

Aim
In this experiment, you will be investigating the vibration of a tuning fork.

Requirements
- 440 Hz tuning fork
- glass beaker

Doing the experiment and writing it up
- Strike the tuning fork. Listen to the tone you hear.
- Strike the tuning fork again. Then place its foot against the table.
- Listen to the tone again.

1 What is the difference, compared to the first time?

- Strike the tuning fork. Touch one prong of the tuning fork with your fingernail.

2 What do you feel?

- Fill the glass beaker three-quarters full with water. Strike the tuning fork. Touch the water surface with one prong of the tuning fork. Take care not to touch the rim of the beaker!

3 What do you see?

- Strike the tuning fork and hold its foot against various parts of your head.

4 When does the tuning fork sound loudest?

Experiment 2 The loudspeaker 15 min

Introduction
Loudspeakers contain a cone-shaped element that can move back and forth, which makes the surrounding air vibrate as well.

Aim
In this experiment, you will be finding out how a loudspeaker makes the air vibrate.

Requirements
- loudspeaker
- two wires
- power supply box

Doing the experiment and writing it up
Connect the loudspeaker up to a DC voltage of 4.5 V (figure 41). Watch the cone as you make the connection.

1 Does the cone move inwards or outwards?

- Swap the two connections on the power supply box over.

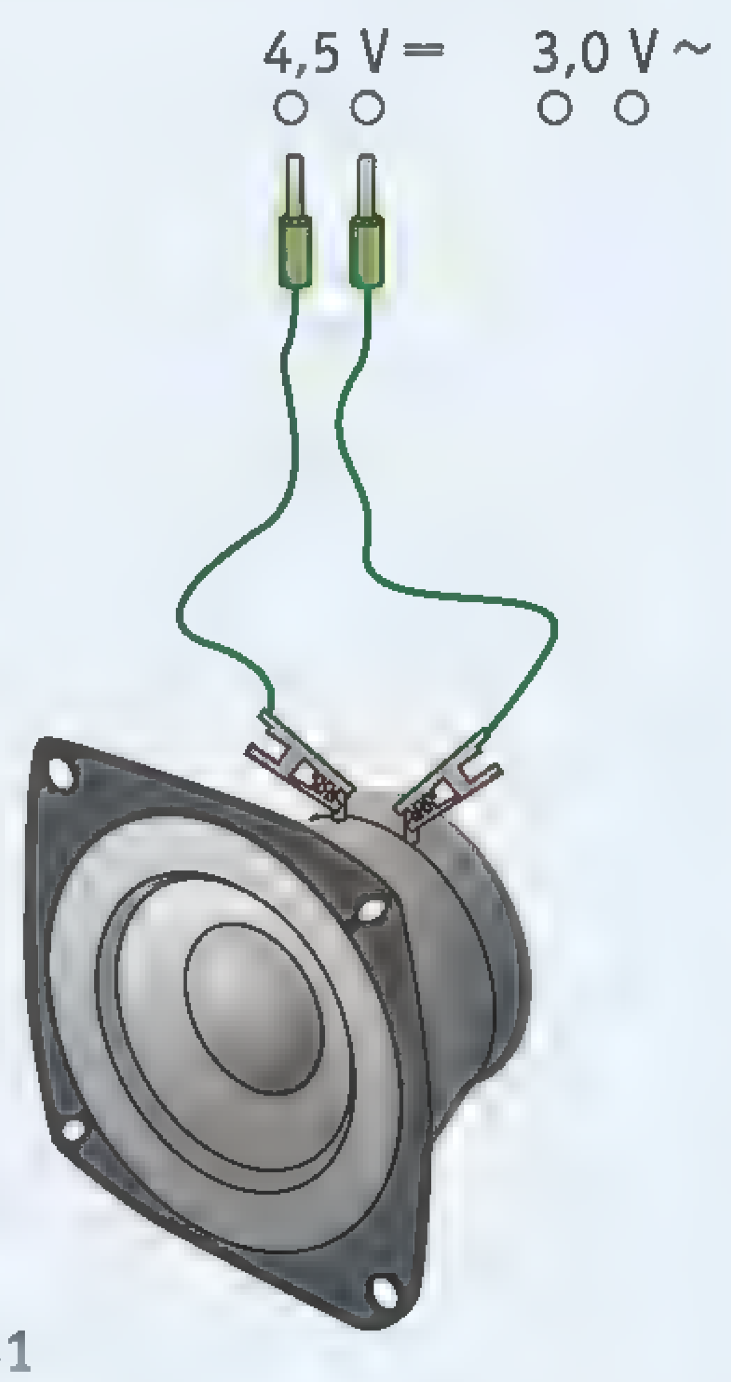
2 Does the cone now move inwards or outwards?

- Now connect the loudspeaker up to an AC voltage of 3 V.
- Note: do not use a voltage of more than 3.0 V!

3 What can you hear?

- Touch the cone gently.

4 What do you feel?



▲ figure 41
the setup for experiment 2

Experiment 3 Your voice as a sound source 30 min

Introduction
When you talk or sing, you use the organs of speech. Your vocal cords produce vibrations that are then modified in the throat and mouth. This is how you generate voiced sounds such as "ah" and "mm". You can also use your tongue and lips to produce voiceless sounds such as 'p' and 's' (in which the vocal cords are not vibrating).

Aim
In this experiment you will investigate how you can use your voice to make all sorts of different noises.

Requirements
- a small mirror

Doing the experiment and writing it up
- Stretch your neck and lift your chin up. Place your fingers on your throat while you say 'mmm'.

1 Describe what you feel with your fingertips when you are saying 'mmm'.
- Hole the mirror just in front of your mouth, about 1 cm away (figure 42).
- Say the following a number of times, clearly and slowly: "The quick brown fox jumps over the lazy dog."

▲ figure 42
Watch carefully how your mouth moves.

2 Describe as accurately as possible the exact sequence for what you see.

- Put the mirror down. Now hold your hand just in front of your mouth while you repeat the same sentence.

3 Describe as accurately as possible the exact sequence for what you feel.

- Shine a light source into your mouth via the mirror, so that you can see right inside your mouth (figure 43).

▲ figure 43
Have a good look at what your mouth is doing.

- Say 'ah' (hold the sound for a while) and look at your mouth in the mirror.

4 Describe as accurately as possible exactly what your mouth is doing.

- Say 'oh' (and hold the sound for a while).

5 Describe as accurately as possible exactly what your mouth is doing.

- Say 'ee'.

6 Describe as accurately as possible exactly what your mouth is doing.

- Put the mirror away.
- Watch your tongue carefully for the next task.
- Say 'rr' (a rolled R in the back of your throat, if you can)

7 What position was your tongue in when you said 'rr'?
8 What did you feel moving in your mouth?

- Keep an eye on your tongue and lips as you say 'ss'.

9 What position did you hold your tongue and lips in when you said 'ss'?
10 Describe how the air was flowing out of your mouth.

- Say the letter 't' a few times.

11 Explain as accurately as possible how you make this sound.

Experiment 4 Tones from strings 30 min

Caution: if you tighten a wire too far it can break. This can be dangerous, because the wire can hit you with quite some force. You are therefore required to wear safety goggles for this experiment.

Introduction
A wide variety of musical instruments produce sound with vibrating strings. A guitar, for example, or a violin or a piano.

Aim
In this experiment, you will be investigating what factors affect the tone a string produces.

Requirements
- safety goggles
- two table clamps
- two wire tensioners
- thin metal wire
- thick metal wire
- tape measure

Doing the experiment and writing it up
- Put your safety goggles on!
- Place the table clamps 50 cm apart and clamp them onto the table.
- Stretch the thin wire between the clamps (figure 44).
- Tighten the thin wire a bit by turning one of the tensioning screws.
- Gently pull the middle of the wire with your index finger and then release it.

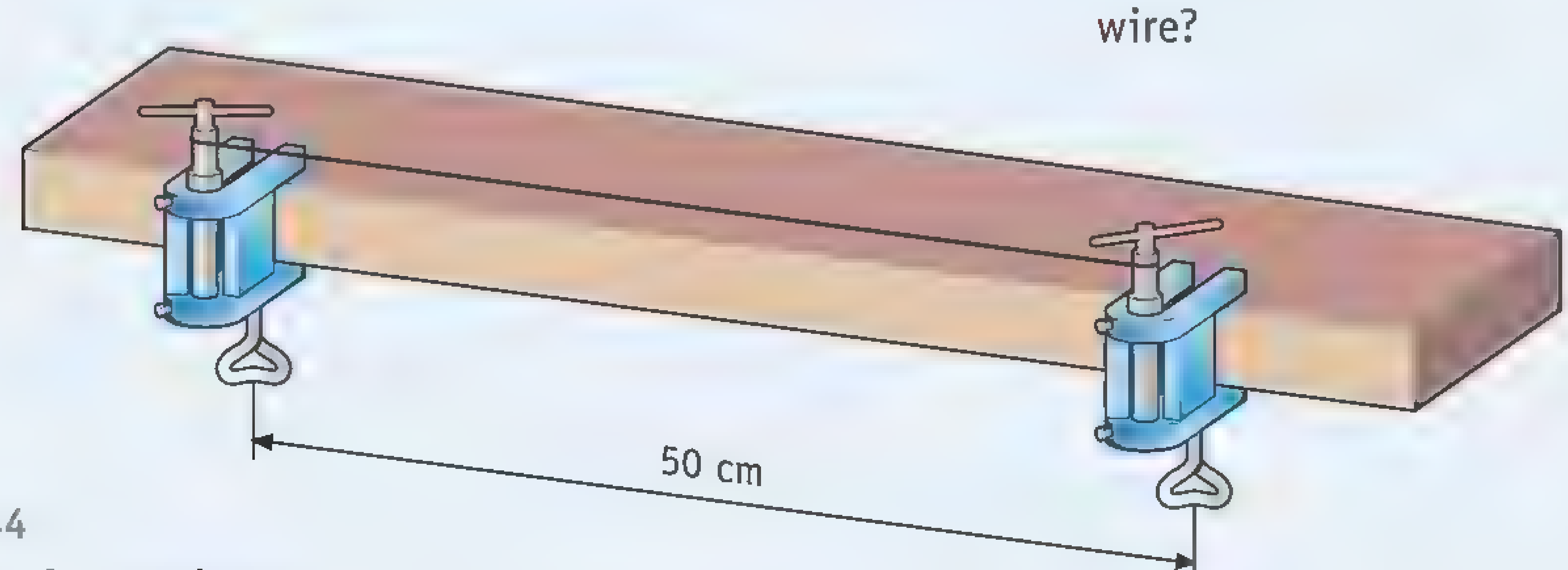
1 How does the wire move?

- Pluck the wire again.
- Listen close to the wire.

2 Can you hear a sound? If so, what do you notice about the sound?

- Pluck the wire again to make it vibrate and then take hold of it again gently.

3 What do you feel?
4 Can you still hear sound when you take hold of the wire?



▲ figure 44
the setup for experiment 4

- Undo the thin wire from one clamp.
- Undo one of the table clamps as well.
- Put the clamps close together, so that the distance is about 25 cm.
- Tighten the wire between the clamps again. Try to judge it so that the tension in the wire is the same as before.
- Pluck the wire again to make it vibrate and listen carefully.

5 Is the tone the same as the first time? If not, what is the difference?

- Undo the thin wire and put it aside.
- Move a clamp so that they are 50 cm apart again.
- Stretch the thick wire between the two clamps. Try to judge it so that the tension is the same as you used for the thin wire.
- Pluck the wire to make it vibrate and listen carefully.

6 Is the tone the same as the one the thin wire gave when it was 50 cm long? If not, what is the difference?

- Now place the clamps 25 cm apart and stretch the thick wire between them. Once again, try to judge the tension in the wire so that it is the same as before.
- Pluck the wire again to make it vibrate and listen carefully.

7 Is the tone the same as the thick wire of 50 cm produced? If not, what is the difference?

- Now tighten the wire a little more.
- Pluck it again to make it vibrate and listen carefully.

8 Has tightening the wire changed the tone? If so, how?

Experiment 5 The vibrating ruler 10 min

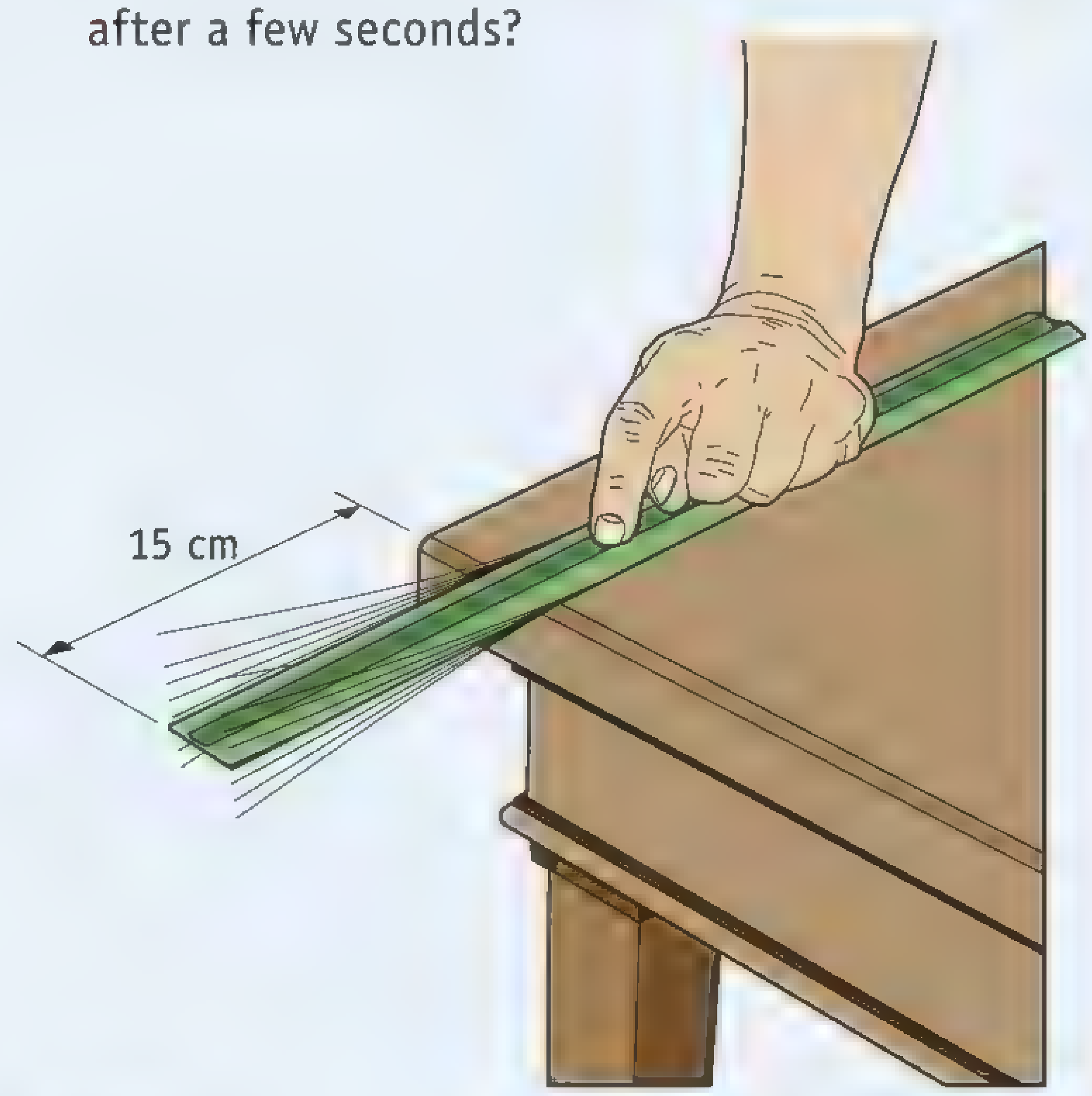
Introduction
A musical scale consists of notes at different pitches. Each note has its own pitch, which depends on the frequency of the sound: the number of vibrations per second.

Aim
In this experiment you are going to make high and low tones using a ruler.

Requirements
- metal ruler

Doing the experiment and writing it up
- Press the ruler down firmly onto the table with your hand, leaving about 15 cm of the ruler protruding over the edge of the table.
- Make the end of the ruler vibrate by plucking it, as shown in figure 45.
- Move the ruler so that 10 cm is protruding over the edge of the table and make it vibrate again.
- Repeat this with 5 cm of the ruler protruding.

1 What differences do you hear between the sounds?
2 When does the sound have the highest pitch?
3 When does the sound have the lowest pitch?
4 How can you tell that the vibration has died out after a few seconds?



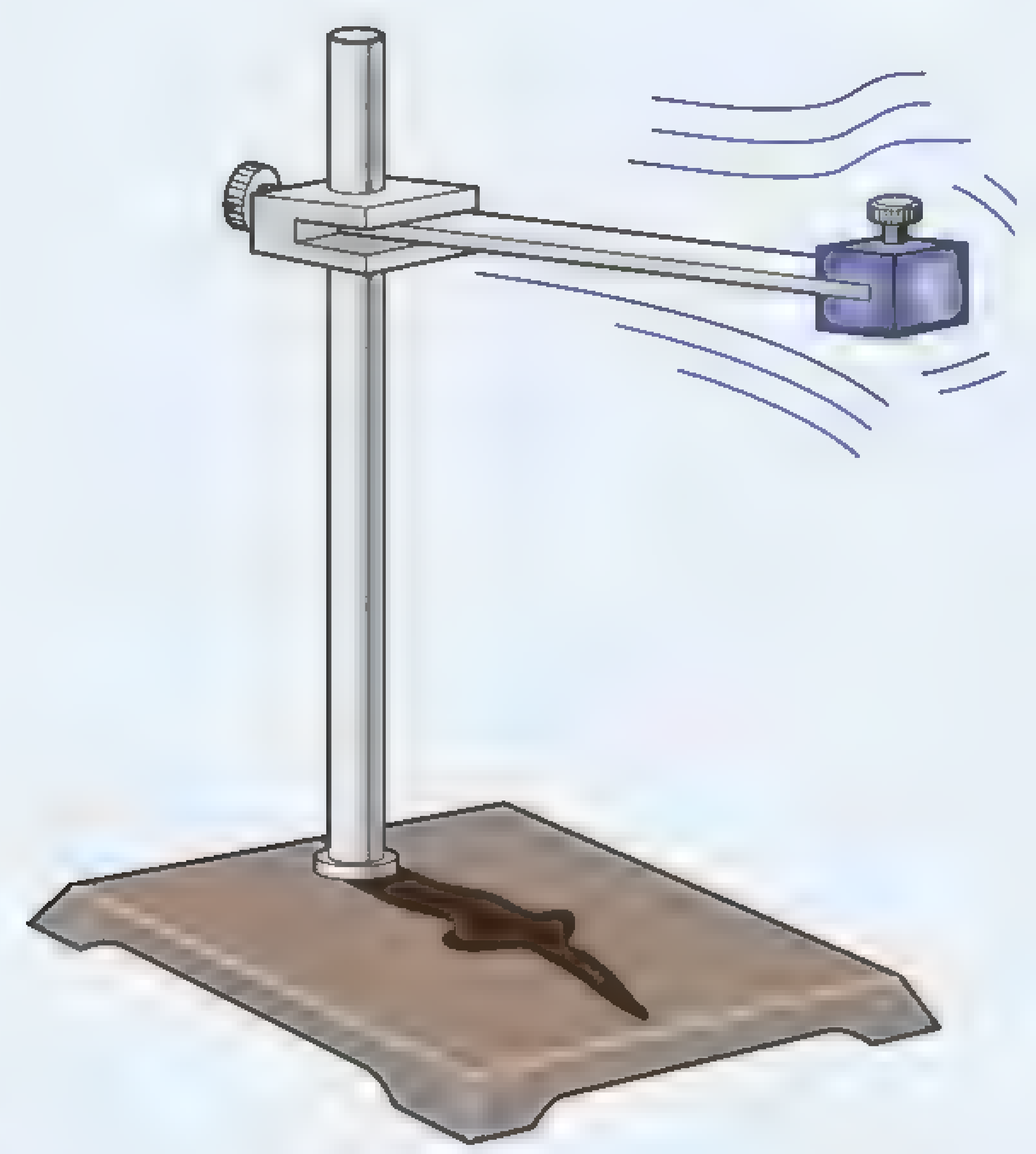
▲ figure 45
This is how to make the ruler vibrate.

Experiment 6 The frequency of a vibration 45 min

Introduction
If you make the end of a hacksaw blade vibrate it vibrates with a fixed period. You can alter the vibration period by attaching a mass to the end of the hacksaw blade.

Aim
You are going to investigate how the frequency of a vibrating hacksaw blade depends on the mass at the end of the blade.

Requirements
- hacksaw blade
- masses of 50 grams
- stopwatch
- stands
- worksheet 7-2



▶ **figure 46**
the setup for experiment 6

Doing the experiment and writing it up
Measuring
- Attach the hacksaw blade to the stand, as illustrated in figure 46.
- Attach a mass of 50 g to the end of the blade.
- Make the blade vibrate. Use the stopwatch to measure the time required for ten vibrations. Do this a total of three times.

1 Copy table 6 into your exercise book. Note down your timings in the table.
2 Calculate the average of the three measurements. Round the result to one decimal place. Write down this value at the correct place in the table.
3 Calculate the time needed for a single vibration. This is known as the period *T* of the vibration. Note this result down in the table.
4 Calculate how many vibrations the hacksaw blade makes in a single second. Round it to one decimal place. This is called the frequency *f* of the vibration.

- Attach masses of 100 g and then 150 g to the end of the hacksaw blade. Determine the frequency of the blade's vibration for each mass.

5 Note down all the measurements in the table.

Writing up
6 Take worksheet 7-2. Draw a graph of your experiment, plotting the frequency against the mass.
7 What conclusion can you draw from the graph?
8 What would happen to the tone made by a tuning fork if you were to screw a weight to each prong?

▼ **table 6** the results of experiment 6

	measurement 1	measurement 2	measurement 3	average	*T* (s)	*f* (Hz)
saw blade with 50 g						
saw blade with 100 g						
saw blade with 150 g						

Experiment 7 Carrying out research: the risks of loud music 45 min

Introduction
Imagine: you read in a newspaper that hearing damage among young people due to loud music is an "underestimated and growing problem". According to the public health service researcher Donné Schmidt, sound levels at music festivals and discos are "much too loud" and are having "an enormous impact". Other culprits are MP3 players and smartphones, which are generally turned up much too loud. According to Schmidt, more than half of young adults have hearing loss of 10 dB or more. You wonder whether it really is as bad as all that and you decide to investigate this yourself.

Aim
In this experiment, you are going to be investigating the noise levels of music to see how much of a risk the listeners are running. Think up a good study question of your own for this research.

Requirements
You can carry out this investigation using a smartphone or tablet onto which you have downloaded a suitable app. You can find an appropriate app by typing in "hearing apps" or "decibel meter apps" (including the quotation marks).

Doing the experiment and writing it up
- Think how you are going to be able to provide a reliable answer to the study question. How are you going to find out what volume is 'normal' for your listeners? How are you going to measure the sound level, and have you chosen the right app? How are you going to define the relationship between your measurement results and the risks being run by the listeners?

1 Make a work plan for this research.

- The work plans will be discussed with the rest of the class at the next lesson. If necessary, you can make improvements to your own work plan after that.
- Then carry out the experiment.

2 Note down all the measurements, calculations and results in your exercise book.

- Your teacher will tell you whether or not you have to write up a report on this experiment.

Nova © Uitgeverij Malmberg

Test Yourself

You can also do questions 1 to 16 on the computer.

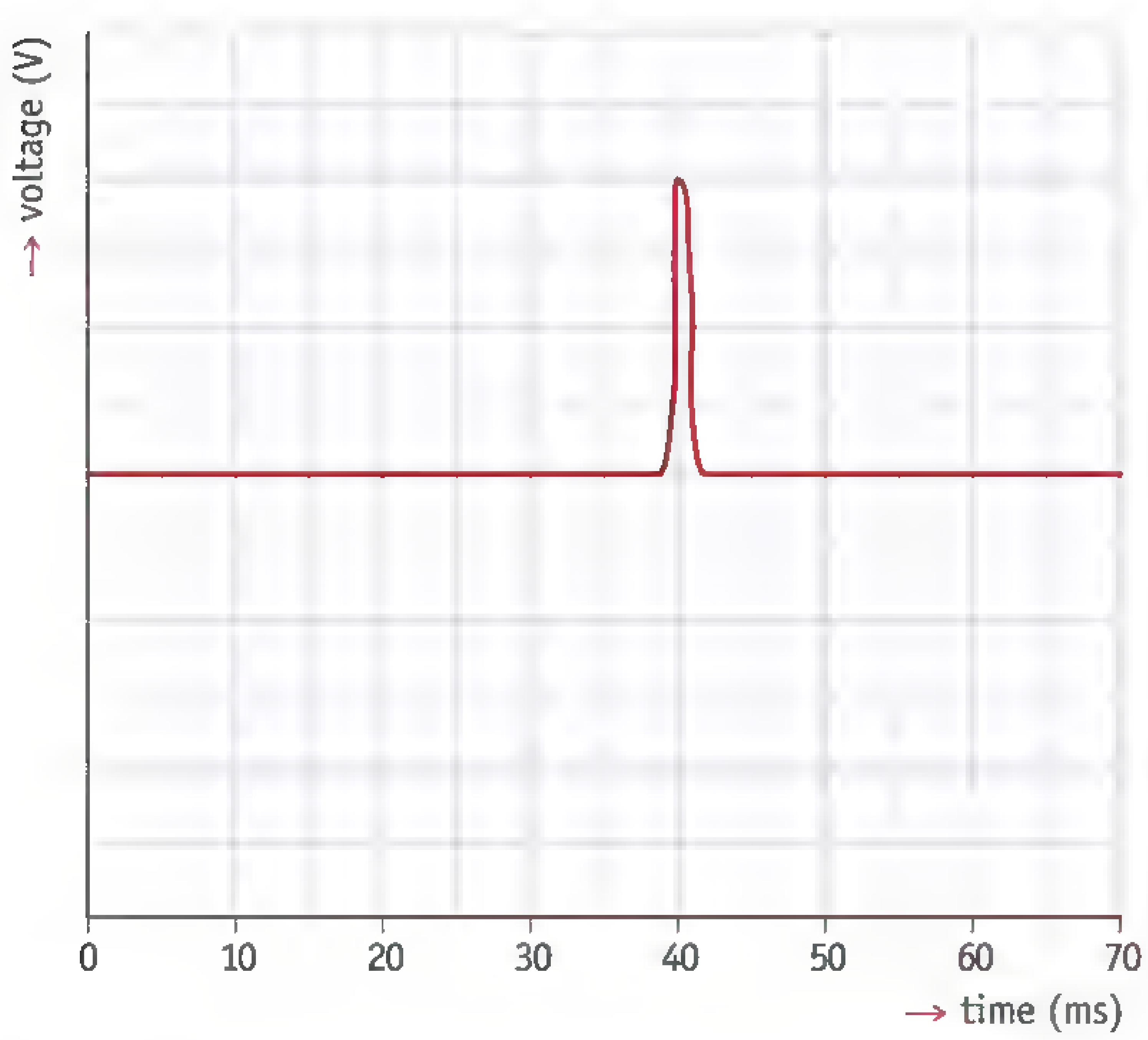
1 Three variables and three units are listed below.
decibel – frequency – sound level – hertz – second – vibration period
a Copy table 7 into your exercise book. Write down the variables on the left, in alphabetical order.
b Put the appropriate units in the right-hand column next to each variable.

▼ table 7 variables and units

variable	unit

2 Danny hears a pupil whistling in the classroom next door. What media does the sound principally have to pass through from the other pupil to Danny's ears? Choose between:
brick – glass – glass – wood – air – paper – water

3 At a fireworks display, Karen sees a rocket explode 136 m above her head. The speed of sound is 340 m/s.
Calculate how much later Karen hears the bang.



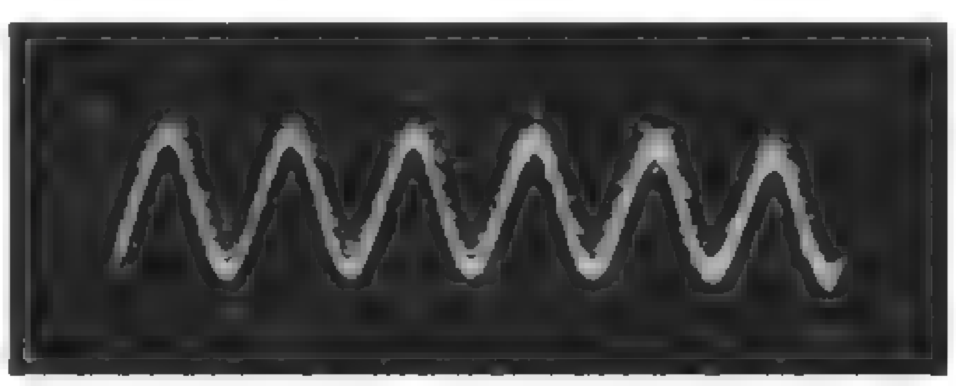
▲ figure 47
What is the speed of sound in rubber?

4 In order to determine the speed of sound in rubber, Gabriel sends a pulse of sound at time t = 0 s through a rubber rod 2.0 m in length. A sensor at the other end registers the arrival of the pulse. The sensor is connected to a computer that displays the measurements in a graph (figure 47).
a How long was it before the pulse reached the sensor?
b Calculate the speed of sound in rubber.

5 An oceanographer wants to determine the depth of the ocean. A transmitter on the research vessel sends a sound signal down. The receiver next to the transmitter picks up the echo after 3.0 s. The speed of sound in seawater is 1.5 km/s.
Calculate how deep the ocean is.

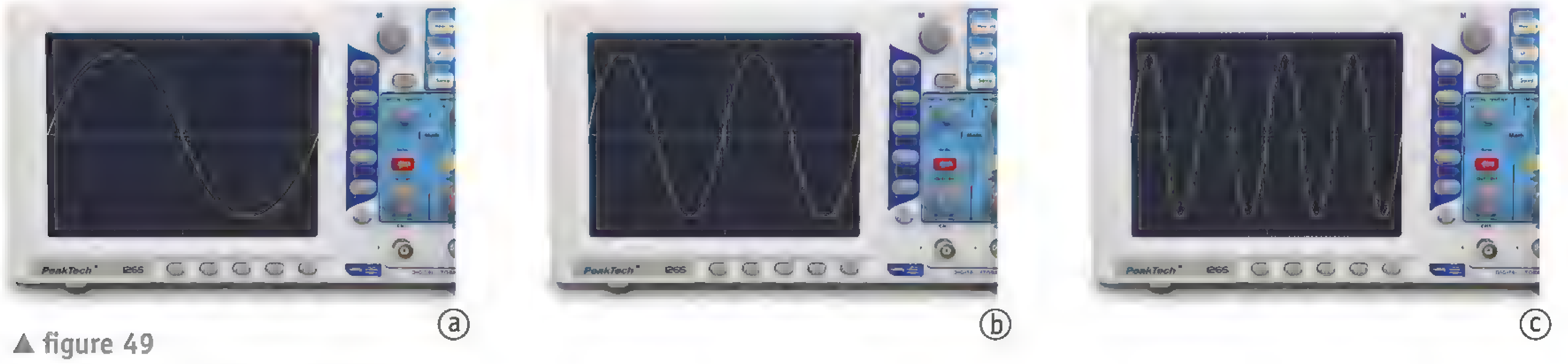
6 A guitarist loosens the tension in one of the strings.
What happens to the pitch?

7 Mark strikes a tuning fork. He then draws a stylus that is attached to one of the two prongs across a glass plate coated with lamp black. The trace he produces is shown in figure 48. The wave trace was made in 0.030 s.
a How many vibrations can be seen in the wave trace?
b Calculate the frequency of the vibrating tuning fork.



▲ figure 48
a wave trace

8 Three tones have been displayed on an oscillo-scope (figure 49).
a The time base for figure 49a has been set to 0.2 ms/div.
Determine the frequency of this tone.
b The time base for figure 49b has been set to 2 ms/div.
Determine the frequency of this tone.
c The time base for figure 49c has been set to 1 ms/div.
Determine the frequency of this tone.



▲ figure 49
oscilloscope pictures of three tones

9 The wings of a bumblebee make a buzzing noise. The frequency of that sound is 250 Hz.

a Calculate how long one complete vibration of the wings takes.

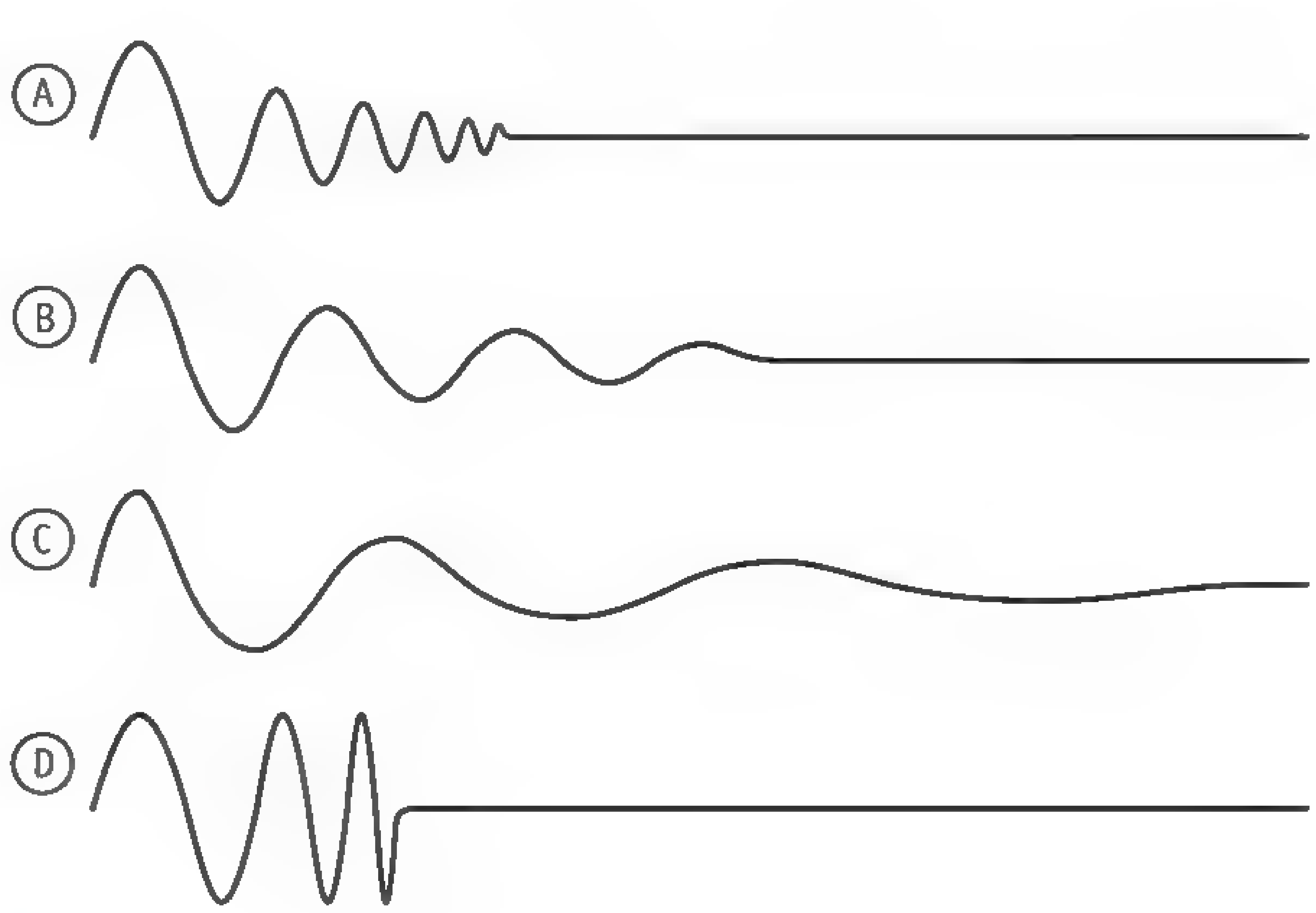
b In order to be able to study the flight of the bumblebee properly, a biologist makes recordings with a high-speed camera. This camera can take as many as 4000 pictures a second. Calculate how many different frames are needed to record one complete wing movement.

10 A piano key is struck twice, first gently and then firmly.
What aspects of the sound vibration does this change?

A the amplitude
B the frequency
C the vibration period
D the amplitude and the frequency
E the frequency and the vibration period

11 A tuning fork with a small stylus on the end is drawn from left to right across a glass plate coated with lamp black. This is done at a constant speed. The vibration dies out as this is done (figure 50).
In which of the four figures is this properly represented, A, B, C or D?

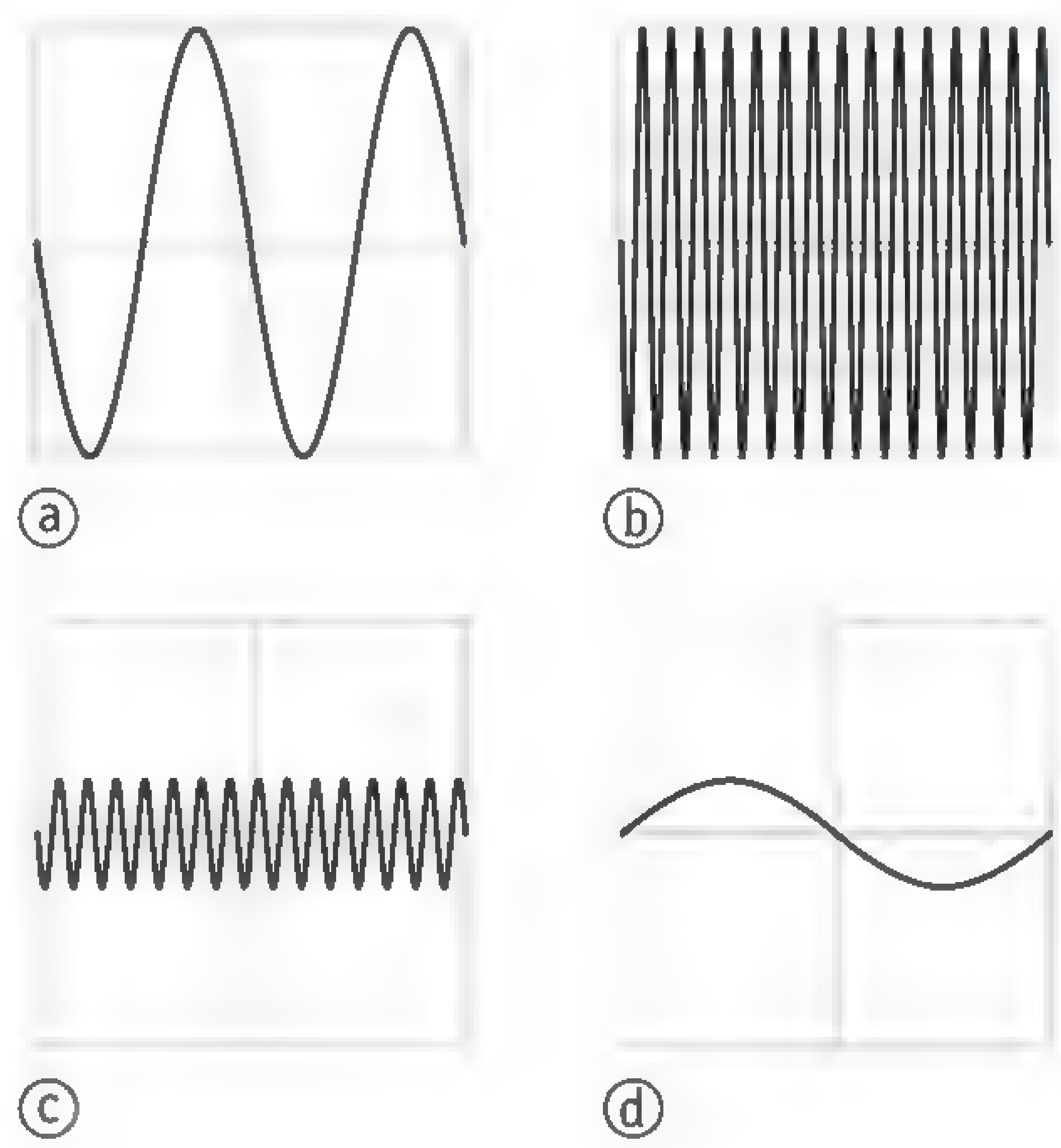
▶ figure 50
Which figure shows you the vibration of a tuning fork dying away rapidly?



12 Figure 51 shows you four different pictures from an oscilloscope screen (all with the same settings).
Which <u>two</u> pictures:

a show the sounds with the highest frequencies?

b show the sounds with the greatest sound intensities?



▲ figure 51
oscilloscope pictures of four different sounds

13 During a saxophonist's solo Tom measures an average sound level of 93 dB five metres from the stage. A little later, three other saxophonists join in, all of them playing equally loudly.
What will the decibel meter read now?

14 Five methods of combating noise nuisance are listed below.
For each of them, state whether the measure is taken:
- at the source (S);
- between the source and the receiver (B);
- at the receiver (R).

a fitting a silencer to the exhaust of a petrol engine
b not permitting noisy aircraft into the Netherlands
c insulating houses that are close to an airfield
d building an embankment as a noise barrier between a motorway and a residential area
e applying low-noise asphalt on through roads

15 Mark the correct option in each case.
Materials that are intended to absorb sound, such as *concrete / glass wool* are *hard / soft* and *smooth / porous*. If you cover a wall with this type of material, it will transmit *more / less* noise. You can show this by measuring the *sound level / frequency* of the sounds that come through it.

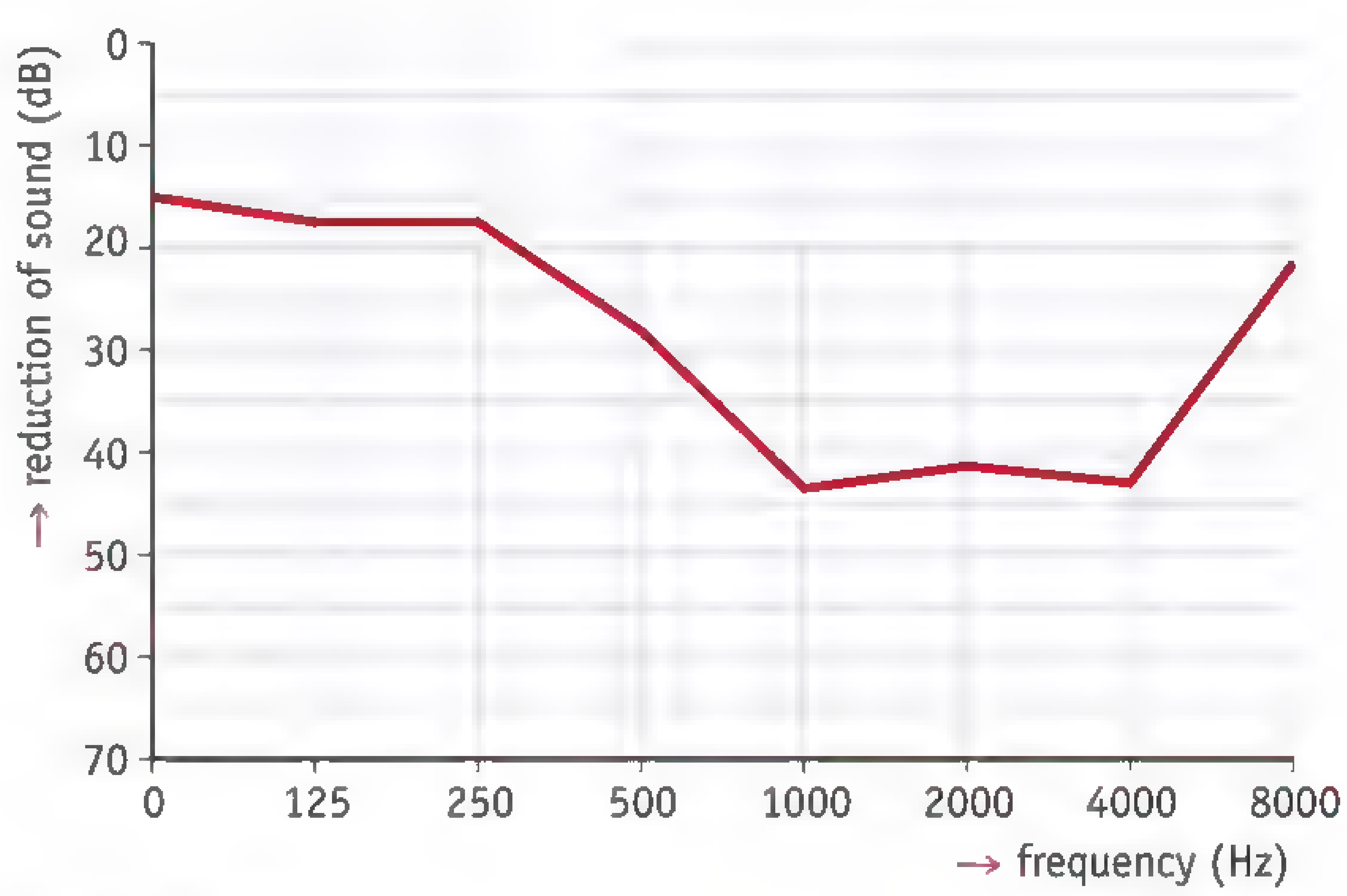
16 Say whether the following statements are true (T) or false (F).
a The sound intensity is usually measured in hertz (Hz).
b Humans can hear tones from 200 Hz to about 200,000 Hz.
c The pain threshold is roughly 140 dB(A).
d Noise levels of 60 dB(A) are not a danger to your hearing.
e Noise barrier screens are intended to reflect sound.

17 An advertisement for vacuum cleaners states that the Samsung VC-6012 produces a noise level of 74 dB(A).
a What does the '(A)' after the units mean?
b What has the manufacturer forgotten to mention when quoting the noise level?

18 Giovanni enjoys singing. He particularly likes singing in the bathroom, because it reverberates around so wonderfully there.
Why is there so much more reverberation in a bathroom than in a bedroom?

19 The blade of a circular saw has 26 teeth. During sawing, the blade rotates at 2400 rpm (revolutions per minute). You can then hear a piercing, high-pitched sound.
Calculate the frequency of this sound. Write your whole calculation down in full. Round the answer to a whole number.

20 The graph in figure 52 shows how much the sound levels are reduced if you wear earmuffs. How much the sound is weakened depends on the frequency of the sound.
a What is the frequency of the sound that is weakened most?
b By how many dB is the level of this sound reduced?
c Would these earmuffs be useful for a musician?



▲ **figure 52**
Earmuffs protect your ears.

***21** Read the article in figure 53.

a Explain whether you can still hear the background noise in this room.

b The walls of this room do not reflect sound. Explain why.

c Explain why it is possible for you to hear your heartbeat in this room.

Quiet enough to drive you mad

In the quietest place on Earth, it turns out that there is no such thing as silence. In the soundproofed 'dead room' in Minnesota, you can hear your heartbeat, your insides burbling, the blood rushing through your veins... Enough to drive you mad.

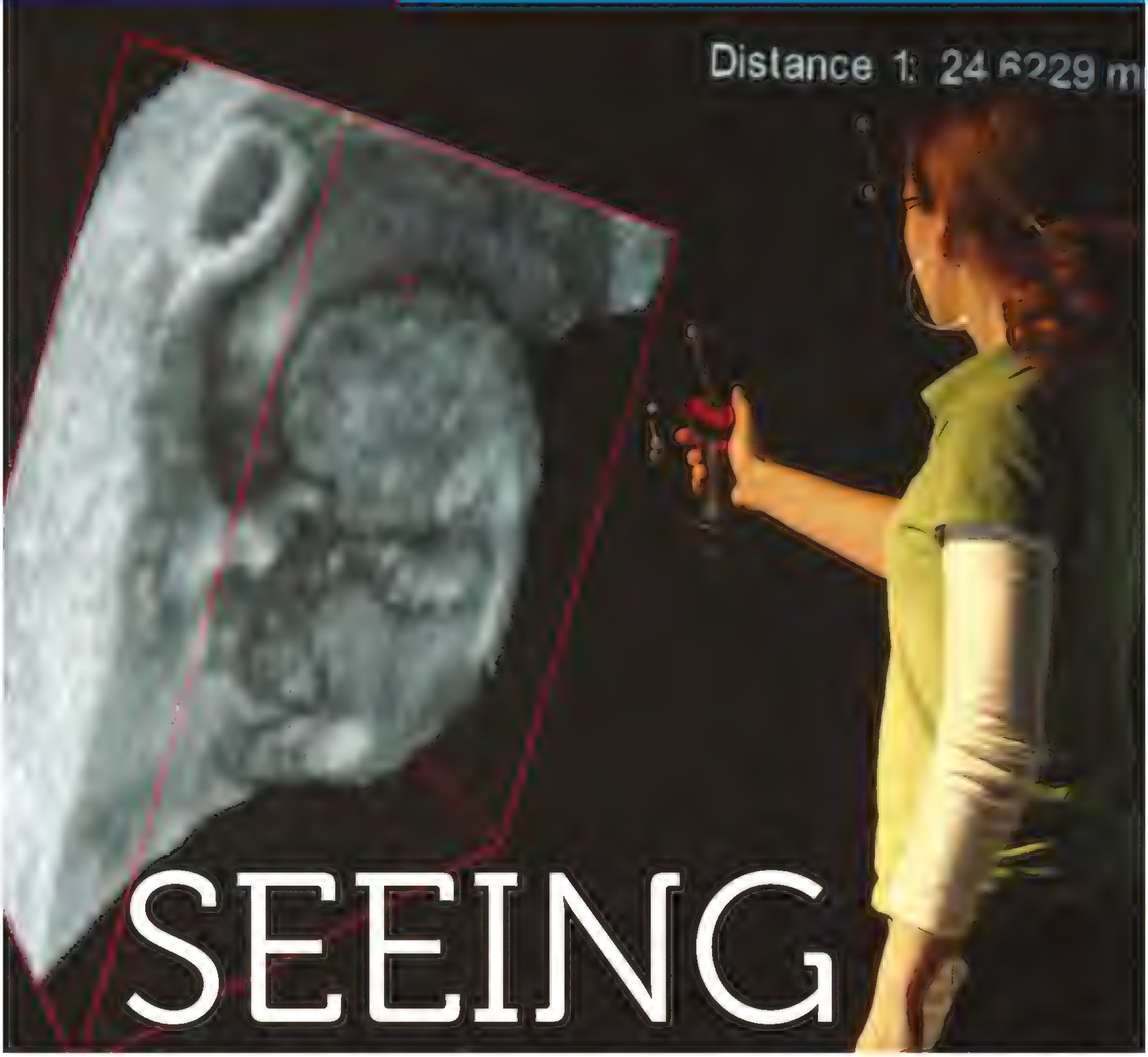
According to the *Guinness Book of Records* this is the quietest place on Earth. In these cacophonous times, that must sound heavenly to many people. But it isn't. Nobody can stay for long in this room. The record is forty-five minutes.

It is certainly extremely quiet: the background noises have been cut down to minus 9.4 decibels. Test subjects inevitably end up wanting to say something, just so that there is some kind of sound around them. However, their shouts disappear into the absorbent layers, many metres thick, on the walls.

Source: Trouw

▲ **figure 53**
the quietest place on Earth

Nova © Uitgeverij Malmberg



SEEING WITH SOUND

“When you put the 3D glasses on you can see the embryo hanging in space before your eyes, hugely magnified and completely three-dimensional. You get the feeling that you could simply reach out and touch it. That feeling gets even stronger if you use the pointer to rotate the baby, so that you can look at it from another angle. If you don’t watch out, you forget that it’s only a picture. Very ingeniously produced, but a picture all the same.”

Doctors at the Erasmus Medical Centre are enthusiastic about a new ultrasonography technique, in which the results of the scan are given a spatial representation. The *virtual reality software* that produces the 3D images has been developed by the Bioinformatics department of the hospital in Rotterdam. Physicians can use the new system to follow the development of an embryo from the first weeks of the pregnancy. This will let them monitor high-risk pregnancies particularly closely.

Sonar: eyes under the water

All sorts of methods have been developed over the course of time to allow 'vision' using sound. The 3D ultrasonography at the Erasmus Medical Centre is the latest step in a long sequence of developments. The basic idea is actually very simple. Sound is reflected at the boundaries between different materials. You can find out where that boundary is located by emitting sound waves and waiting until the reflection – the echo – comes back to you.

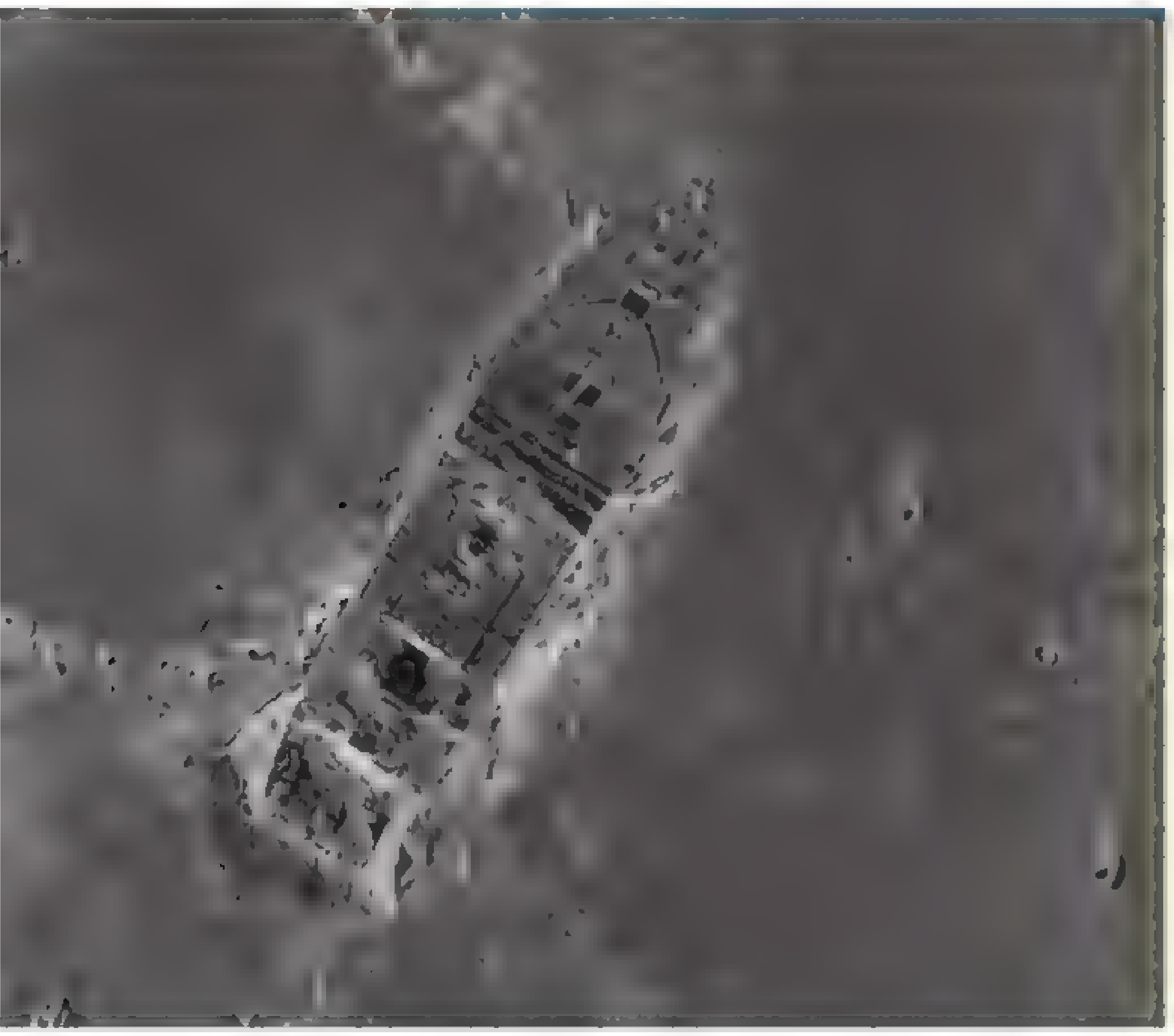
Sonar can therefore be used to detect icebergs under the water.

The first application of this basic idea was in sonar (an abbreviated form of *sound navigation and ranging*). This is a technique that uses sound to let you detect objects under the water surface. For example, sound is reflected very strongly at the boundary between ice and water. Sonar can therefore be used to detect icebergs under the water. That is extremely useful, because 90 per cent of an iceberg is under water and so it can present an invisible hazard.

Sonar became a great success. The technique was used not only for detecting icebergs, but also for navigating in shallow waters and for locating shoals of fish. During the Second World War sonar was an important tool for detecting enemy submarines. Using sonar was one of the reasons that the Allies won the submarine battle against Nazi Germany.

An explosive experiment

Other ideas for using sound to create images of objects soon appeared. In 1921, a group of researchers in the United States



Sonar images of the Titanic

The first patent for sonar was applied for in 1912, one month after the famous passenger ship Titanic had collided with an iceberg and sunk. The disaster cost the lives of more than 1500 people. In 2012, a century later, the wreck of the Titanic was accurately mapped using advanced sonar cameras. The images are a convincing demonstration of just how far the technology has now come.

carried out an experiment to test one such idea. They exploded a large dynamite charge in order to send powerful sound waves into the ground. Just like the inventors of sonar, they were interested in the reflections that might be generated.

The researchers knew that the sound waves would bounce back at the boundary layer between two different rock strata, but they did not know if the reflections would be strong enough for them to be detected on the surface. It turned out that they were strong enough, and so reflection seismology was born. This technique is now used throughout the world for discovering subterranean gas and oil reserves

Echoes from inside the body

The success of sonar and reflection seismology gave physicians an idea: maybe they could use sound to produce images of the inside of the body. After all, there are all sorts of boundary layers within the body as well, for example between soft tissue and hard bone.

It became clear very quickly that they were not going to get far with normal sound. The things that a doctor wants to see are far smaller than an iceberg or a rock stratum and so you cannot use normal, audible sound for visualising them. That needs ultrasound, which has a much higher frequency and therefore a much shorter wavelength: the sound waves are much closer together and capable of being used to produce images of smaller objects.

The first medical experiments with ultrasound were carried out between 1940 and 1950. The researchers attempted to use it to localise brain tumours. It was not a great success. It did produce an image of the brain, but the image remained very unclear. What was clear, though, was that the researchers were onto something useful. The technique was perfected in the years that followed until good, clear images could be produced with it.

Having a scan

Ultrasonography – having a scan or a 'foetal echo' – uses a sonde that contains a series of piezoelectric crystals. The electronics make these crystals emit a short pulse of ultrasound. The sound propagates through the body, with reflections occurring at the boundary layers between different tissues. The crystals pick

up the echoes again and convert them into an electrical signal.

A computer uses the signals from the crystals to build up an image of the body. To produce that image, an average speed of sound of 1540 m/s inside the body is assumed. The speed of sound is not actually exactly the same in all tissues, but the average speed nevertheless gives a usable result. One key advantage of ultrasonography is that you can use it to investigate soft tissues that cannot be seen on an X-ray.

Before the examination starts, the sonographer smears a special gel on the skin. The gel is needed to ensure good contact between the sonde and the body. If there is air between the sonde and the skin, a very strong reflection comes back from the boundary between the air and the skin, because they are two totally different 'materials'. The sound waves are then reflected before they can even get into the body, and that naturally does not produce good pictures.

Echoes in 3D

By putting a number of cross-sections together, a computer can build up a three-dimensional image. The result is normally viewed on an ordinary screen or printed out on normal paper. The image itself only has two dimensions, although it is representing a three-dimensional situation. That type of image cannot generate the illusion of 'real' depth. As yet, doctors at the Erasmus Medical Centre are the only ones who can see an ultrasound scan floating in space in three dimensions.

Exercises

1 To determine the position of the reflection, the computer uses an average value of 1540 m/s for the speed of sound. People who are obese (very overweight) have thick layers of fat. The average speed of sound in fat is lower, between 1462 and 1473 m/s. Explain whether a fat layer will appear too thick, too thin or at the right thickness in ultrasonography.

2 The first ultrasonography devices were very large, much bigger than the sondes that are used now. To have an echo, the patient had to sit in a bath.
Think what the reason might have been for making the sonogram under water.

***3** You cannot see details on an echo that are smaller than the wavelength of the sound used. The wavelength is the distance between successive peaks of the sound waves (the areas in which the pressure is higher than average).
a Sound at 1540 Hz has a wavelength of about 1 metre in the human body.
Use the data from this article to show that this statement is correct.
b The sounds used for ultrasonography have frequencies of 1 to 10 MHz.
Calculate the wavelength of this sound.

8 Light

A world full of light

Light is needed not only to be able to see things. It also provides colour and atmosphere. Lighting designers and architects use light to create precisely the effects that they want, whether that is a spectacular lighting show or an attractively lit town centre.

1 Light and colour

▲ figure 1
The Sun breaking through the mist.

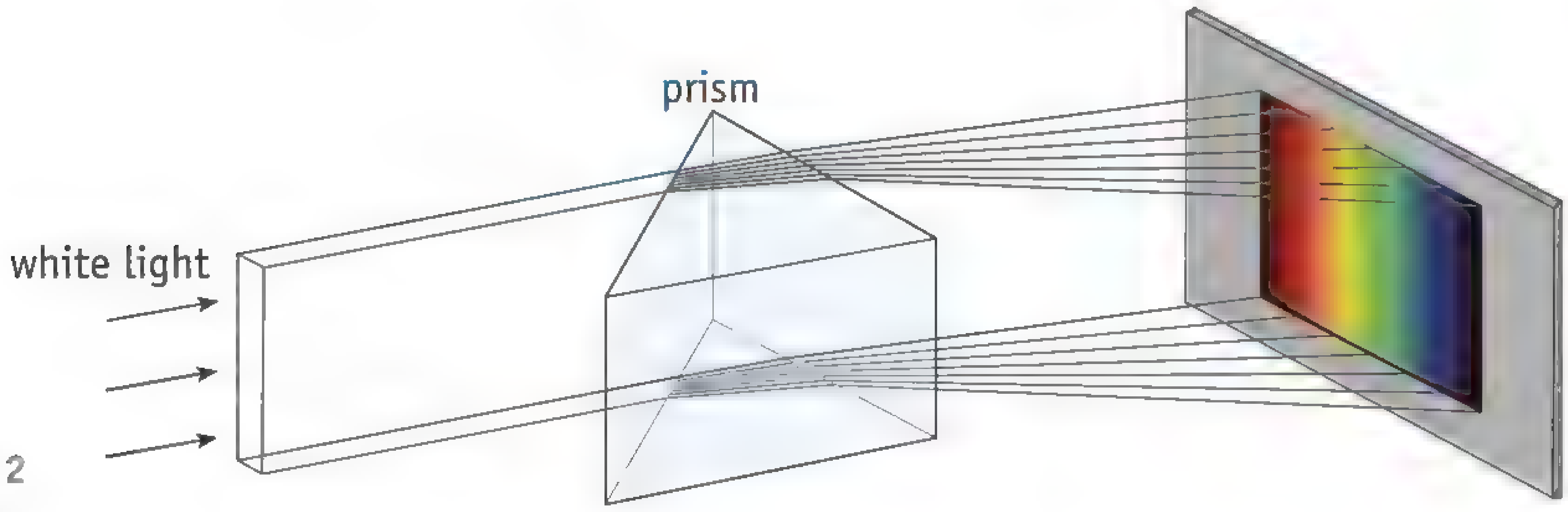
When it is misty you can sometimes see the Sun appear through the mist as a clear white disc. You can get a good look at the Sun then because the Sun is not as blindingly bright as usual. That is no longer possible when the mist has cleared and you can see the world around you again in full sunlight.

Light from the sun

The Sun is a fairly small star, one of at least two hundred billion stars in the Milky Way. Because the Sun is far closer to the Earth than the other stars, it is the most important **natural light source:** without sunlight, life on Earth would be inconceivable.

The Sun's white light comprises all the colours of the rainbow. This can be demonstrated by letting sunlight pass at just the right angle through a triangular piece of glass called a **prism** (figure 2). A whole series of colours can then be seen on a screen placed behind the prism: red, orange, yellow, green, blue and violet. A sequence of colours like this is called a **spectrum.**

You can use a second prism to merge the various colours of light in the spectrum back together. You then get the original white of the sunlight back again. Experiments like these show you that sunlight is a mixture of different **spectral colours** (the pure colours in the spectrum).



▶ figure 2
Making a spectrum with a prism.

Seeing your surroundings

Most of the things you can see around you do not emit light themselves. You can only see them when they are illuminated. The light that falls on the object is then **reflected diffusely** (in all directions). You see the object when a proportion of this reflected light enters your eyes.

During the daytime, the objects around you are lit by the Sun. You then see the world 'in colour' (figure 3). The various colours arise because many objects only reflect part of the sunlight falling on them. For example, something that is red reflects principally the spectral colour red, and a blue object reflects principally the spectral colour blue. The remaining light is absorbed by the object and converted into heat.

▶ figure 3
Colours arise because the light is reflected differently.

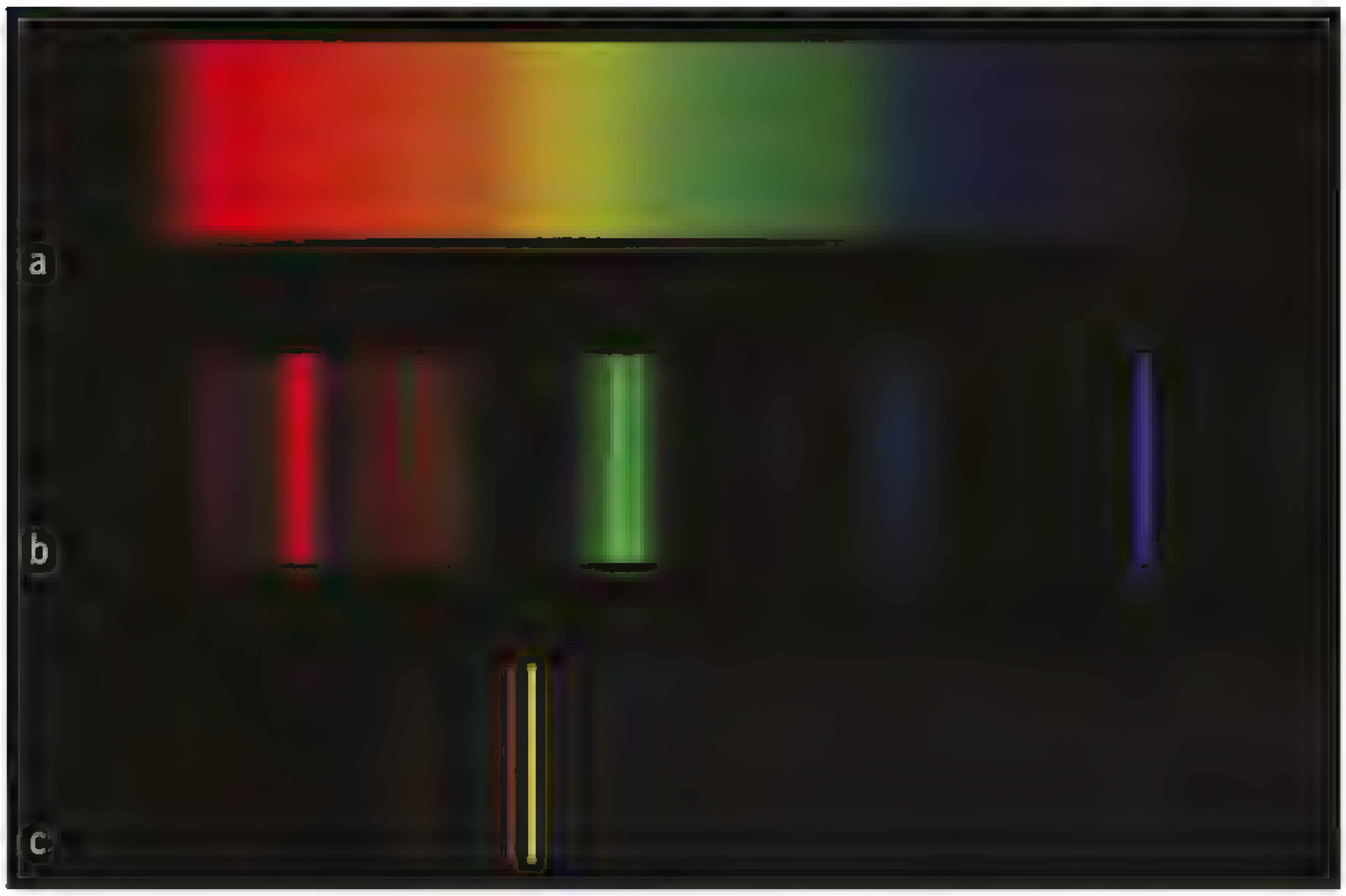
White objects reflect almost all the sunlight falling on them. All the spectral colours are reflected to the same extent. The reflected light therefore has the same composition as the original sunlight. Black objects, however, reflect very little light. Almost all the sunlight is absorbed, irrespective of the colour of the light.

The spectrum of lamp light Experiment 1

Candles, light bulbs and fluorescent tubes are **artificial light** sources: they have been manufactured by humans. You can use a pocket **spectroscope** to study the light that they emit. If you look at a light through a spectroscope like this, you see a spectrum of the lamp light (figure 4). This lets you determine the spectral colours that make up that light.

◀ figure 4
How to use a pocket spectroscope.

A halogen bulb and a fluorescent tube both emit white light. But if you look at the spectra of these lights you will see clear differences. The spectrum of a halogen bulb is continuous, much like that of sunlight (figure 5a). The spectrum of the light from a fluorescent tube is dominated by certain spectral colours (the bright lines), whereas other spectral colours are very weak (figure 5b). Coloured objects can look different in this kind of light compared with their appearance in sunlight.



▶ figure 5
spectra of a halogen bulb, a fluorescent tube and a sodium lamp

When choosing light sources, people do not only look at the amount of light: the colour of the light is also important. Light that contains a lot of red, orange and yellow gives a warm impression. Light that has a lot of green and blue is neutral, or can even seem cold. Warm light is used a great deal in rooms that are intended to be cosy and friendly. For work areas, clear white, neutral light is generally used.

▲ figure 6
This street is lit by SOX sodium lamps.

Sodium lamps

Experiment 2

There are also light sources that just emit a single colour of light. A **sodium lamp** (low-pressure sodium or 'LPS' lamp, type SOX) emits light with a pure yellow/orange colour, for example. Their spectrum comprises just two narrow lines in the yellow/orange range (figure 5c). Sometimes you can also see a red/orange line, which comes from neon gas.

The world looks very different under sodium lighting from what you normally see (figure 6). For example, a purple jumper can look dark grey or black. This is because the jumper almost completely absorbs the yellow/orange light of the sodium lamp. A white jumper and a yellow jumper will both look yellow under a sodium lamp. The yellow light of the sodium lamp is reflected equally strongly by both jumpers.

Plus Screen colours

A TV or computer screen is made up of light-emitting strips, dots or squares that are called **subpixels**. Whatever their shape may be, the subpixels always have the same three colours: red, green and blue. You can see that if you look at a screen using a strong magnifying glass (figure 7). From a normal viewing distance, the individual subpixels all merge together to give a single picture in all kinds of colours.

Each subpixel can be switched on and off individually. In a part of the image that is red, only the red subpixels will be emitting light; in a green part of the image it will only be the green subpixels, and so forth. Other colours are made by mixing red, green and blue light. Yellow, for example, is produced by making the red and green subpixels light up together. Green and red light mixed together give the same impression as pure yellow light.

▼ **figure 7**
All the colours on a TV screen are made using three colours of light.

The reason why red and green together make yellow has to do with the way your eyes work. There are three different types of cones (light-sensitive cells) in the retina, each with its own colour sensitivity. One type responds best to red, orange and yellow light; another to yellow, green and blue light; and the third responds to blue-green, blue and violet light. A mixture of red and green light gets a response from the first two types of cones in exactly the same way as pure yellow light does – and we therefore perceive it as yellow.

Exercises

1 Answer the questions below.
- a Which six (spectral) colours make up the spectrum of sunlight?
- b What does a red object do to the sunlight falling on it?
- c What does a black object do to the sunlight falling on it?
- d What instrument can you use to examine the light emitted by a lamp?
- e What does a white object look like under sodium lighting?

2 Copy and complete:
- a Objects that do not emit light themselves can only be seen if they are ....
- b The light that falls on such an object is reflected ...... (i.e. in all directions).
- c You see the object when part of the reflected light reaches your ....

3 Not all light sources give the same 'type' of light.
a Which natural light source gives clear white light?
b Which artificial light sources gives pure yellow/orange light?

4 Table 1 shows four differently coloured items of clothing.
Copy table 1 into your exercise book and record:
a a plus sign (+) if the item of clothing largely reflects the light.
b a minus sign (–) if the item of clothing largely absorbs the light.

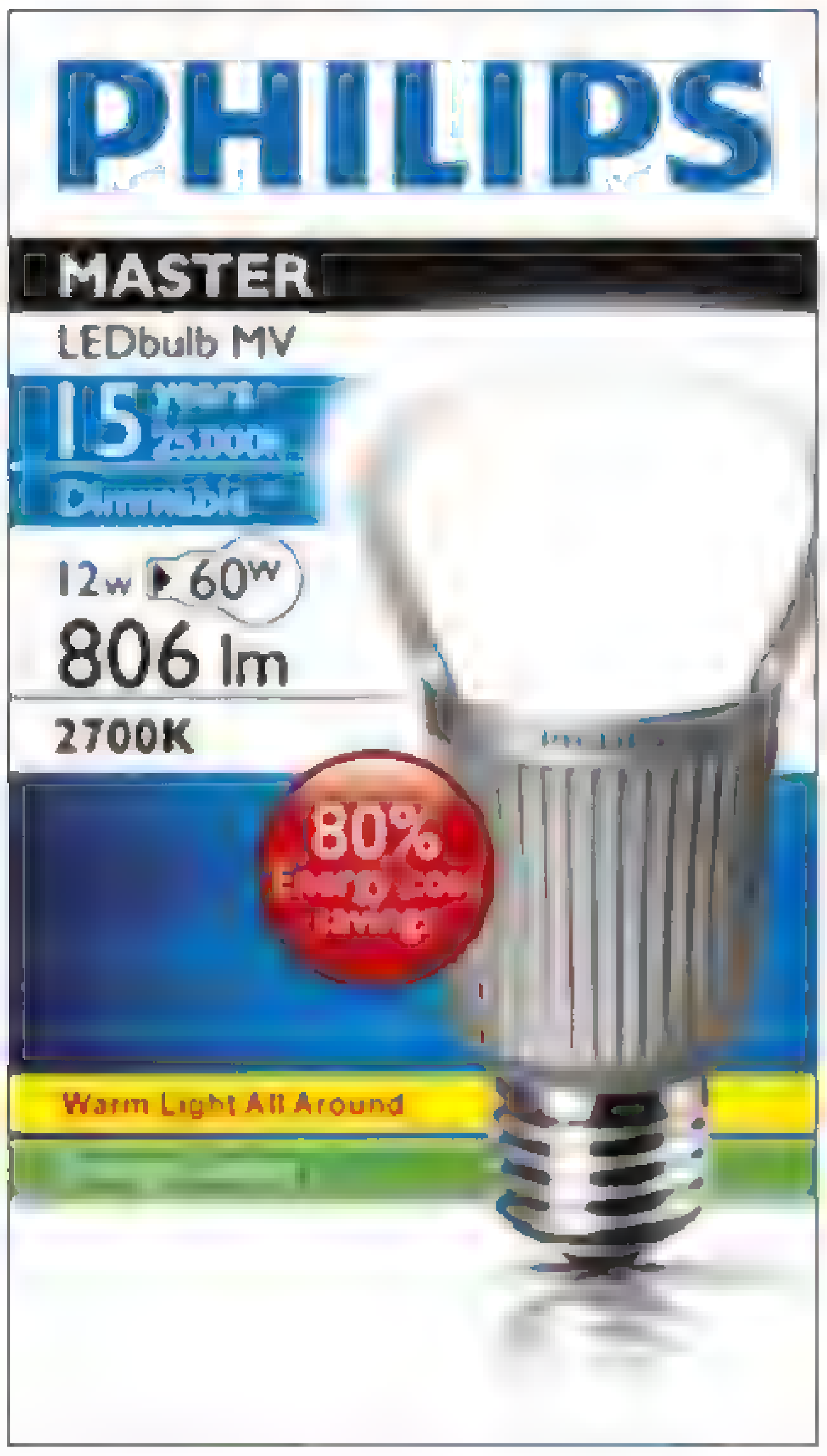
▼ **table 1** reflected or absorbed

clothing item	pure red light	pure green light
white T-shirt		
green T-shirt		
red T-shirt		
black T-shirt		

5 Compare the two photographs in figure 8.
a Which photo was taken in clear white daylight?
b What lighting was used for the other photo?
c In which photo do the colours appear as they really are?
d What is the real colour of the coffee cup?
e What colour does the coffee cup appear in the other photo?
f What causes the colour to appear different?

▲ **figure 8**
two photographs of Melanie

6 Jasmine is out shopping in a shop that uses fluorescent lighting. She has found a jumper that she thinks looks really good. But, before she buys it, she takes it to the door first so that she can see it in daylight.
What is the point of doing that? Explain.



▲ figure 9
part of the packaging of a LED lamp

7 The packaging of light bulbs often states their colour temperature. That tells you what kind of colour light the bulb produces. Light with a low colour temperature (e.g. 3000 K) contains a relatively large amount of red light. Light with a high colour temperature (e.g. 6500 K) contains a relatively large amount of blue light.

- **a** What colour temperature is stated on the packaging in figure 9?
- **b** What kind of impression will the light from this bulb make: warm, neutral or cool?
- **c** Is the light from this bulb suitable for judging colours?
- **d** Is the light from this bulb suitable for creating a warm and cosy atmosphere?

8 Dennis plays football for Stoke in a white shirt with red stripes. If he walks under a low-pressure sodium lamp he will appear to turn into a player from a different football club.
Which club is it?

- A Newcastle United (black and white stripes)
- B Sheffield Wednesday (blue and white stripes)
- C Hull City (black and yellow stripes)
- D Crystal Palace (blue and red stripes)

***9** Car parks often used to be lit with low-pressure sodium lighting. This type of light is being used less and less often now because it makes colours very difficult to recognise.
Explain why:

- **a** colours cannot be recognised properly under this type of lighting.
- **b** this gives problems in large car parks with large numbers of vehicles.
- **c** people are more likely to feel unsafe with this type of lighting.

Plus Screen colours

10 The screen of a mobile phone is made up of subpixels.

- **a** What are the colours of these subpixels?
- **b** Which subpixels light up:
  - in a part of the image that is green?
  - in a part of the image that is red?
  - in a part of the image that is yellow?

11 Sometimes you will see an old black-and-white film on the TV.

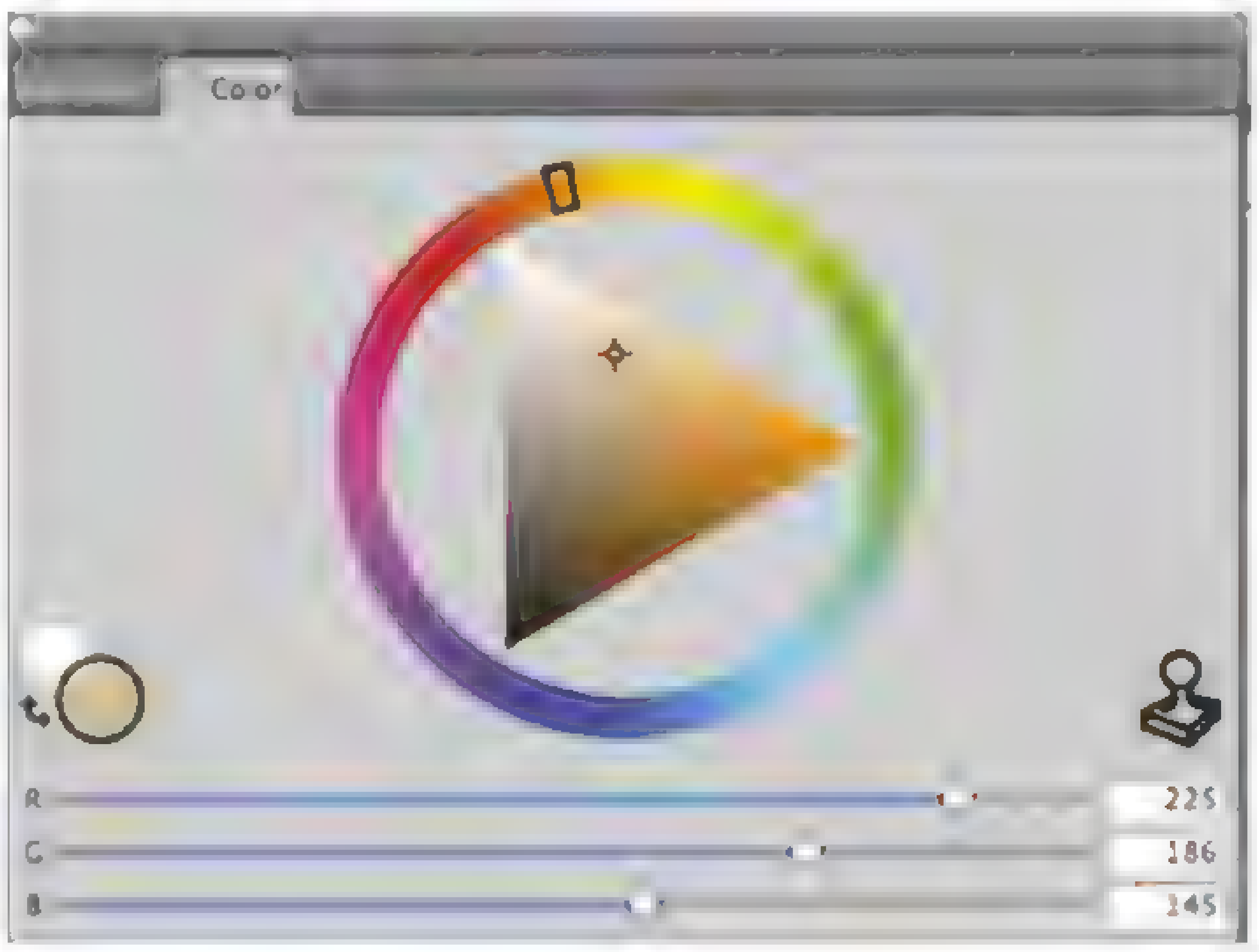
- **a** How does the screen create the black parts of the picture?
- **b** How does the screen create the white parts of the picture?
- **c** How does the screen create the grey parts of the picture?

*12 Read the text in figure 10 about RGB colour coding.

a Copy the following RGB codes down in your exercise book.
State what colour each of the RGB codes represents.
- (255, 0, 0)
- (0, 255, 0)
- (255, 255, 0)
- (255, 255, 255)
- (128, 128, 128)
- (128, 128, 255)

Use the 'Edit colours' option in a program such as *Paint* to check your answers.

b The RGB code was specially developed for describing screen colours. How can you tell that?



The RGB-code

Computer programs such as Paint and Photoshop give a code to every colour. This code is called the RGB code, which stands for red (R), green (G) and blue (B). Every RGB code consists of three numbers ranging from 0 to 255. These numbers tell you how much red, green and blue there is in the colour. The larger the number, the more red, green or blue is used.

The RGB code for bright red is (255, 0, 0): lots of red (255), no green (0) and no blue (0). Magenta – bright violet – is (255, 0, 255): lots of red (255), no green (0) and lots of blue (255). Black is (0, 0, 0): no red, no green and no blue.

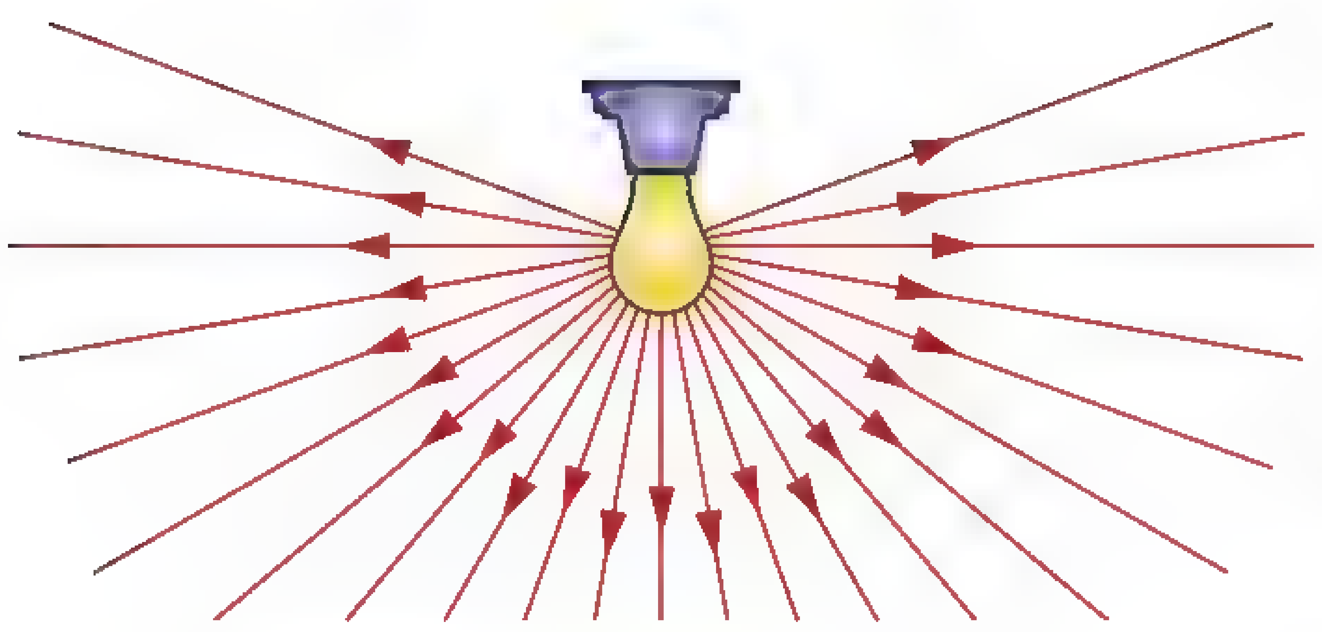
▶ figure 10
explanation of RGB colour coding

2 Direct, indirect and diffuse

On the beach on a hot summer's day, light is coming from all directions: directly from the Sun, reflected by the sand and the sea, and scattered by the air above your head. Even in the shade you need sunglasses so that you do not have to squint as you look around.

Light and shade

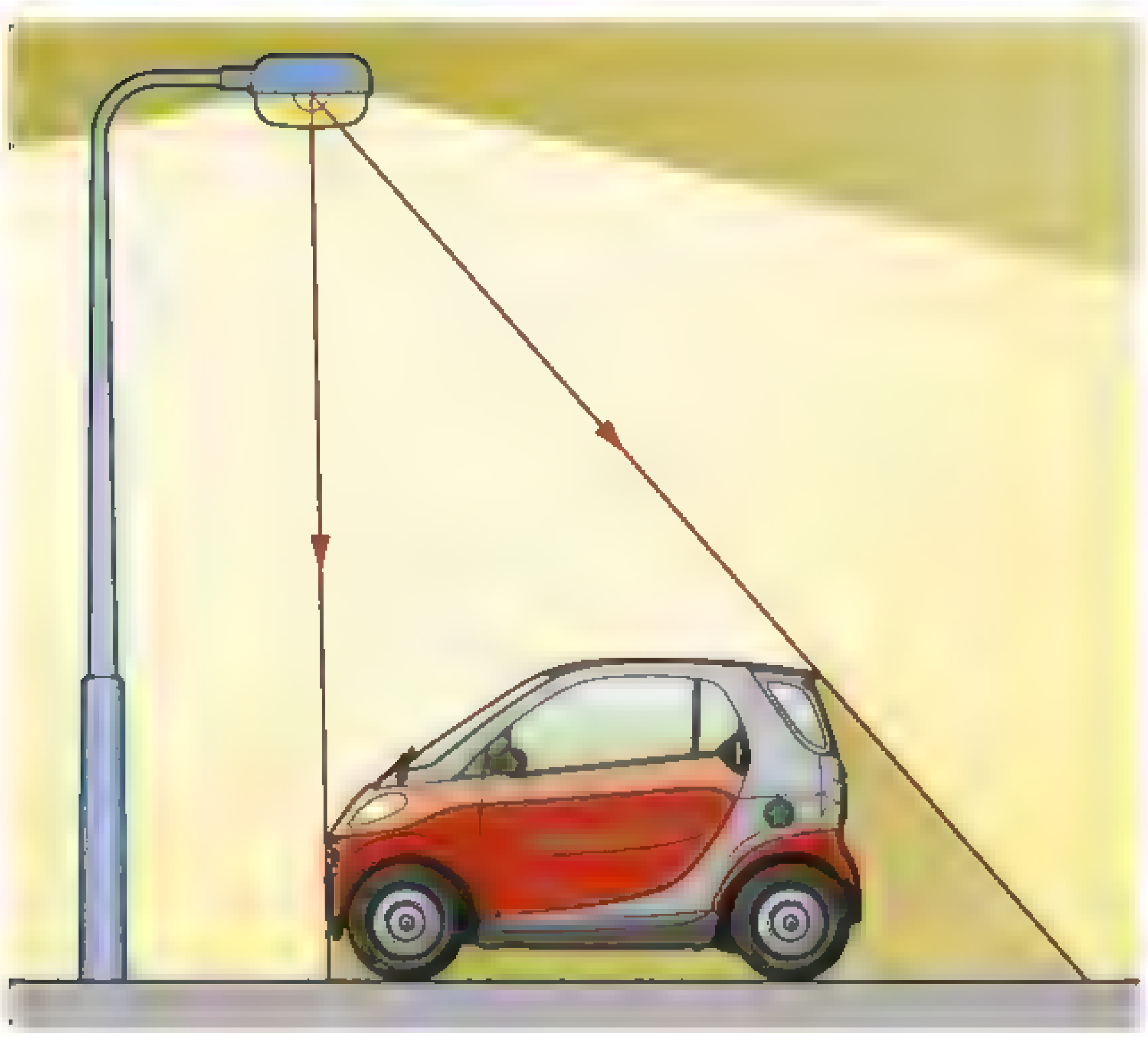
The light that is radiated by a light source spreads out in all directions. You can indicate that by drawing in **rays.** The rays are straight, because light moves in straight lines (figure 11). The greater the distance from the light source, the weaker the light. You can see that because the rays become more and more separated.



▲ figure 11
The rays show how the light moves.

If an object blocks the light from the light source, it creates a **shadow.** There is then a region that the light cannot get to directly. Because light moves in straight lines, it is easy to determine the size of the shadow area (figure 12):

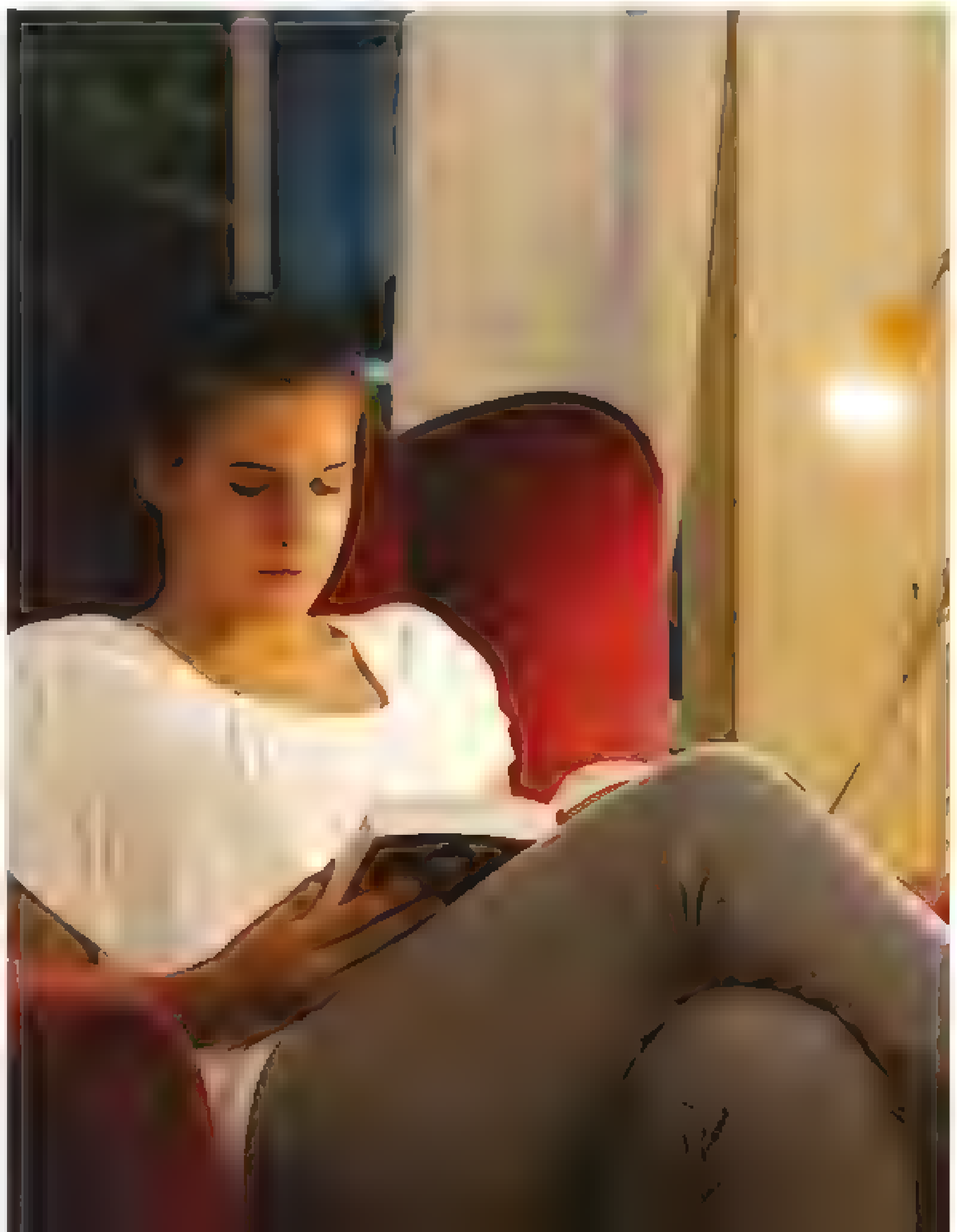
1 Draw in the two rays that are not quite blocked by the object (the 'edge rays').
2 Hatch in the area behind the object that is in between the two edge rays. This is the area that the light cannot reach directly.



▲ figure 12
How to draw in the shadow of an object.

Direct light Experiment 3

Most household jobs are done indoors on a table, desk or worktop. The working surface has to be well illuminated. This should preferably be done with lamps that provide **direct light.** That is to say, the light goes directly from the light source to the working surface, as for the reading lamp in figure 13.



▶ figure 13
A lamp providing direct light.

A reading lamp does not provide appropriate lighting for a worktop surface with tools and other working materials. You then get dark shadows everywhere, with a sharp boundary between light and dark. It can make it difficult for you to see exactly what you are doing. The shadows also distract you from what you really want to be seeing.

Having two lights next to each other can help. You then get double shadows, one from each lamp. The darkest parts of the worktop are where the two sets of shadows overlap. This is called the **umbra**. To the left and right of the umbra, you can see the lighter **penumbra**. Light can reach this area from one lamp but not the other (figure 14).

▶ figure 14
umbra and penumbra

▲ figure 15
a lamp that provides indirect illumination

A fluorescent tube gives nice fluid transitions from light to dark. The amount of direct light reaching the worktop decreases gradually in the transitional regions. You can see that the penumbra slowly gets darker until it blends imperceptibly into the umbra.

Indirect and diffuse light

Lighting is widely used to create a pleasant, inviting atmosphere. The lamps used for this kind of lighting do not give direct light. That is too 'harsh' and business-like. Mood lighting has to illuminate the whole space 'softly', without patches of bright light and deep shadow. This can be done using indirect light or diffuse light.

Figure 15 shows you a lamp that gives **indirect light**. The light from the bulb does not shine directly into the room, but is aimed instead at a white wall. The wall reflects the incident lamplight in various directions. This makes it seem as if the entire wall is a single illuminating area: an **indirect light source**.

The lamp in figure 16 uses a different method to produce a 'soft' light. The light from the bulb fall on translucent paper, that **scatters** the light in all directions. The ball becomes an indirect light source, just like the wall in figure 15. The light that you obtain this way is called **diffuse light**.

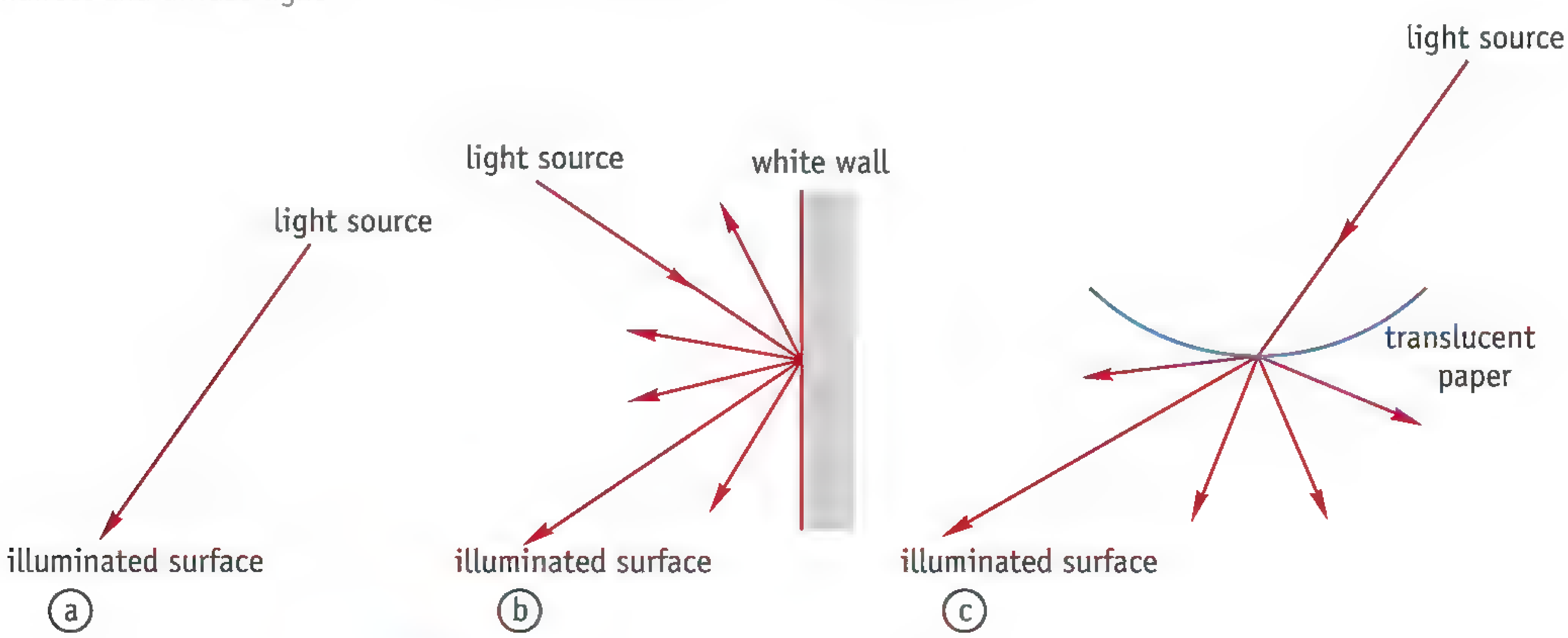
▶ figure 16
a lamp that gives diffuse light

Reflection and scattering

Indirect and diffuse light are often used in combination with direct light. They soften the 'harsh' shadows that are created if you use direct light alone. Because the light is coming from a large area it can reach all sorts of places where there is no direct light. This makes the contrast between light and shade much less.

Indirect and diffuse light therefore have the same effect. There is, however, a difference in the way in which they are produced. Indirect light is created by reflection: the light rebounds off a non-translucent surface, such as a white ceiling. Diffuse light is created by scattering: the light changes direction as it moves through a translucent material, such as paper, frosted glass or textile (figure 17).

▼ figure 17
direct, indirect and diffuse light

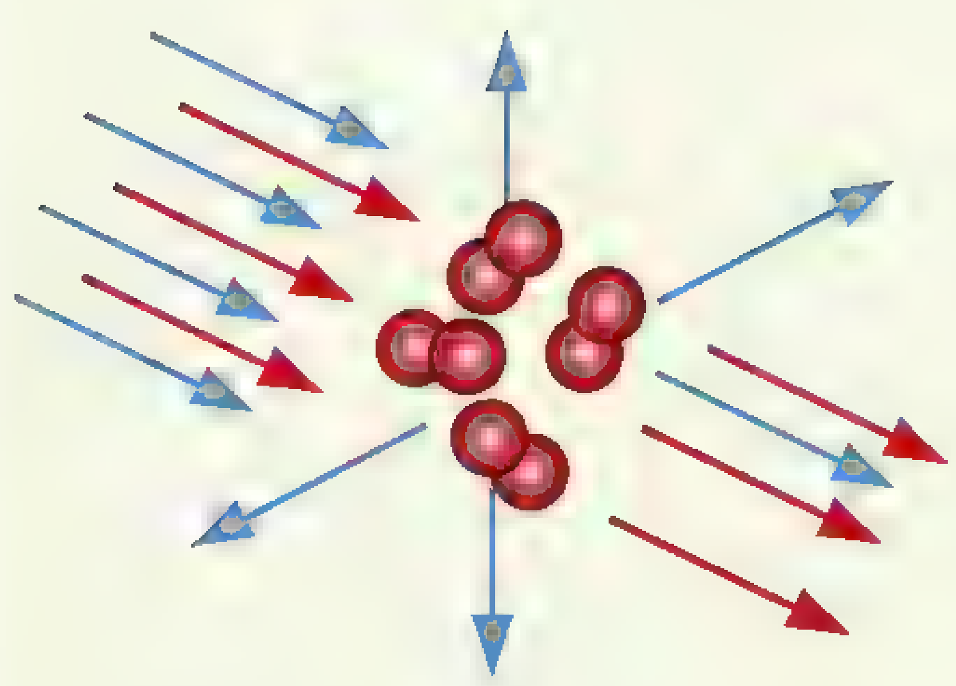


Reflection and scattering are not merely concepts for lighting technology: they also determine how you perceive the light outdoors. Sand and snow reflect the sunlight that falls on them, so that you have to squint with your eyes almost closed. Clouds and mist scatter the sunlight, giving a modified, diffuse light, with almost no shadows.

Plus Blue skies and red sunsets

If you look up on a cloudless day, you see that the sky is deep blue everywhere. The light reaching your eyes is perceived as blue. In reality, this blue is a mixture of various spectral colours. There is a lot of violet in it (though your eyes are not so sensitive to that), quite a lot of blue, a bit of green and almost no yellow or red; the mixture of these spectral colours is seen as sky blue.

The blue colour of the sky arises because the air molecules scatter the sunlight (make it change direction). You do not notice that in a thin layer of air. The air then appears perfectly transparent. But in the atmosphere, which is several kilometres thick, the scattering is clearly visible. Violet and blue are the spectral colours that are most strongly scattered, and red and orange are affected least. This means that the scattered light makes the sky blue (figure 18).



▲ figure 18
Sunlight is scattered by the molecules in the atmosphere.

At sunset, the sunlight has a longer path through the atmosphere before getting to your eyes. Almost all the violet and blue light has been scattered out of it by then. Because the red light is scattered much less (and can largely pass straight through the air), it is the dominant colour in the remaining light. That makes the setting sun look red.

Exercises

13 Copy and complete:
- **a** Light rays show you how light moves away from a ....
- **b** The rays are ......, because light goes in ...... lines.
- **c** The greater the distance from the light source, the ...... the light.
- **d** You can see that because the rays become more and more ....

14 A worktop is lit by not one but two lamps hung up next to each other.
- **a** Why does every object on the worktop have two shadows?
- **b** What is the name for the area on the worktop where the shadow is darkest?
- **c** Why are there also two lighter areas of half-shadow?
- **d** What kind of shadows do you get if you replace the lamps with a fluorescent tube?

15 Answer the questions below.
- **a** Why are lamps that give direct light not suitable for creating a pleasant and cosy atmosphere?
- **b** What two types of light are provided by lamps that are used for mood lighting?
- **c** Why do people perceive the light from these kinds of lamps as 'soft'? What does the word 'soft' imply?

16 You need worksheet 8-1 for this exercise.
The worksheet shows you a bulb hanging above a stool.
Draw in the two edge rays. Hatch in the shadow area between them.

17 You need worksheet 8-2 for this exercise.
The worksheet shows you Peter, who is standing beneath a streetlight.
- **a** Draw in the bulb of the streetlight at the right place.
- **b** Peter is 1.80 m tall. How high above the ground is the bulb of the streetlight? Write down, step by step, how you got your answer.

18 You need worksheet 8-3 for this exercise.
The worksheet shows you a fluorescent tube hanging above a stool.
- **a** Draw in the two edge rays from the left-hand edge of the fluorescent tube.
- **b** Draw in the two edge rays from the right-hand edge of the fluorescent tube.
- **c** Use blue to show where you can see the umbra of the stool.
- **d** Use red to show where you can see the penumbra areas of the stool.
- **e** A mouse crosses the floor of the room from the left-hand wall to the right, going under the stool. Describe how the light on the floor changes for the mouse as it progresses.

19 In figure 19 you can see a standing lamp with a reading lamp.
- **a** What type of light does lamp 1 give?
- **b** What do you use that light for?
- **c** What type of light does lamp 2 give?
- **d** What do you use that light for?

***20** Explain why:
- **a** the light beams of a laser show up much better if it is slightly misty than they do in dry weather.
- **b** shadows in sunny weather are 'hard' and have sharp edges, whereas you hardly see any shadows if the weather is cloudy.
- **c** people on winter sports holidays have more difficulty with blinding sunlight than tourists hiking round the mountains in the summer.

◀ **figure 19**
standing lamp and reading lamp

▲ figure 20
two portrait photos

21 Figure 20 shows two portrait photos. The photographer used a flash for both photos.

- **a** Which portrait photo used a very 'harsh' light?
- **b** How can you see that the light in this photo was 'harsh'?
- **c** How can you see that the light in the other photo was 'soft'?
- **d** Explain why photographers often choose to aim the flash via the ceiling, instead of directly.

***22** The basic equipment of a professional photographer includes a white umbrella (figure 21).

- **a** According to the text, in what two ways can a photographer use this type of umbrella?
- **b** Which of the two ways is shown on the photo in figure 21? How can you see that?
- **c** Draw how the umbrella, the flash and the model are arranged for the other method.
- **d** The light is softer if the photographer places the umbrella closer to the model.
  Explain why.
- **e** "A large umbrella produces softer light than a small one," claims a website.
  Explain whether this statement is correct or not.

The umbrella can be used in two ways, namely as a reflector or as a diffuser. When the umbrella is being used as a reflector, the flash is directed into the umbrella and reflects back onto the model via the open side of the umbrella. When used as a diffuser, the umbrella is set up with the outside facing the model. The flash is directed into the umbrella in this case as well, but the light now passes through the umbrella fabric and lights the subject. The bigger the umbrella, the larger the light source illuminating the model.

Source: www.123cursus-fotografie.nl [translated]

▶ figure 21
part of a photography course

Plus Blue skies and red sunsets

23 Answer the questions below.

- **a** Which spectral colours make up the blue of a cloudless sky?
- **b** Why does blue predominate in the light that reaches your eyes from a cloudless sky?
- **c** Why does red predominate in the light that reaches your eyes from the setting sun?

24 Search the Internet for photographs that have been taken on the Moon and on Mars. Suitable search terms could be 'surface' and 'Moon' or 'Mars'.
How can you tell:

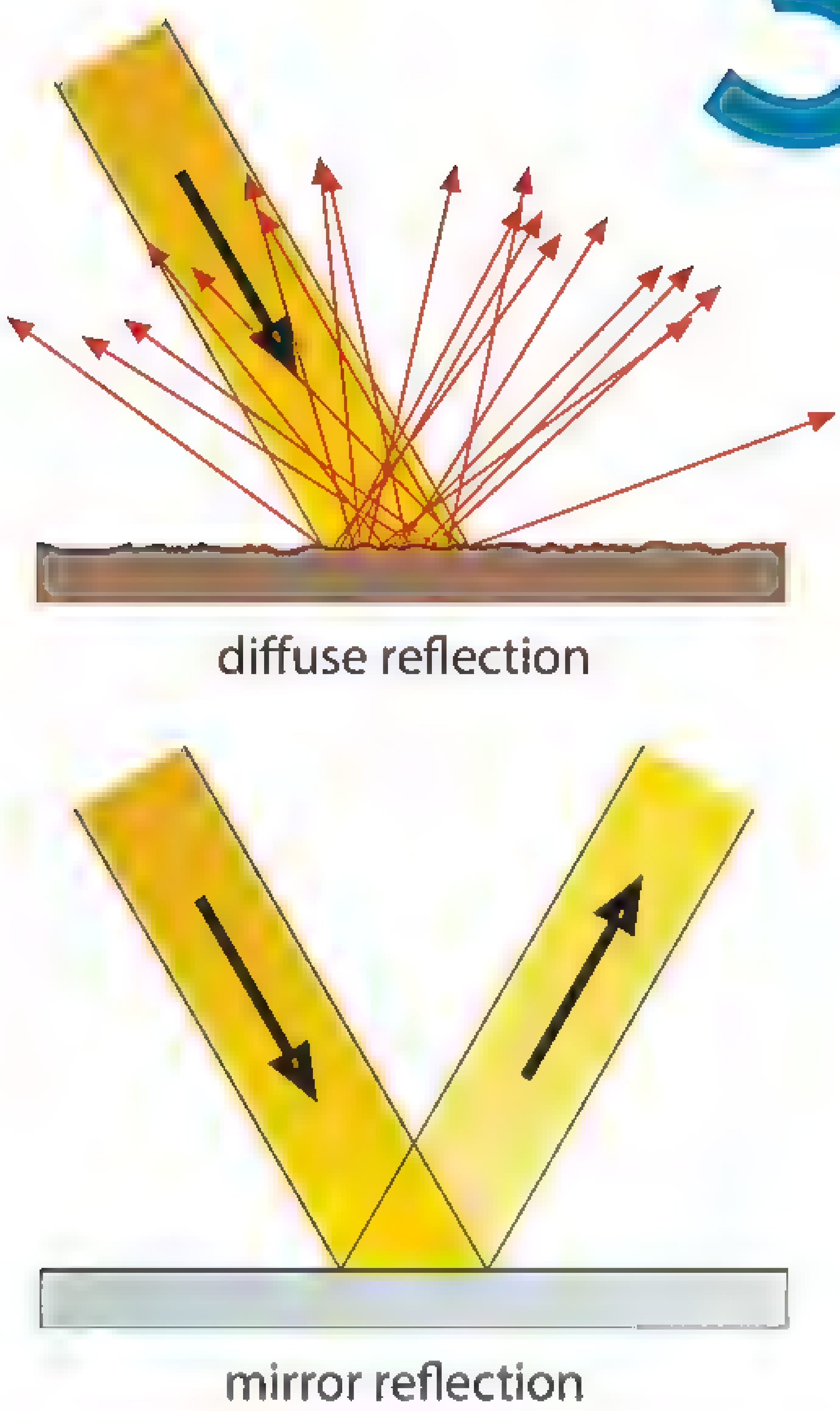
- **a** that Mars has an atmosphere but the Moon does not?
- **b** that the atmosphere on Mars contains a lot of blown dust?

***25** A mountainous landscape in the distance looks very different to when it is seen close by (figure 22).

- **a** Describe the differences in colour, contrast and brightness.
- **b** Explain the role that the scattering of light has in this.

▶ figure 22
a mountainous landscape

3 Mirror images



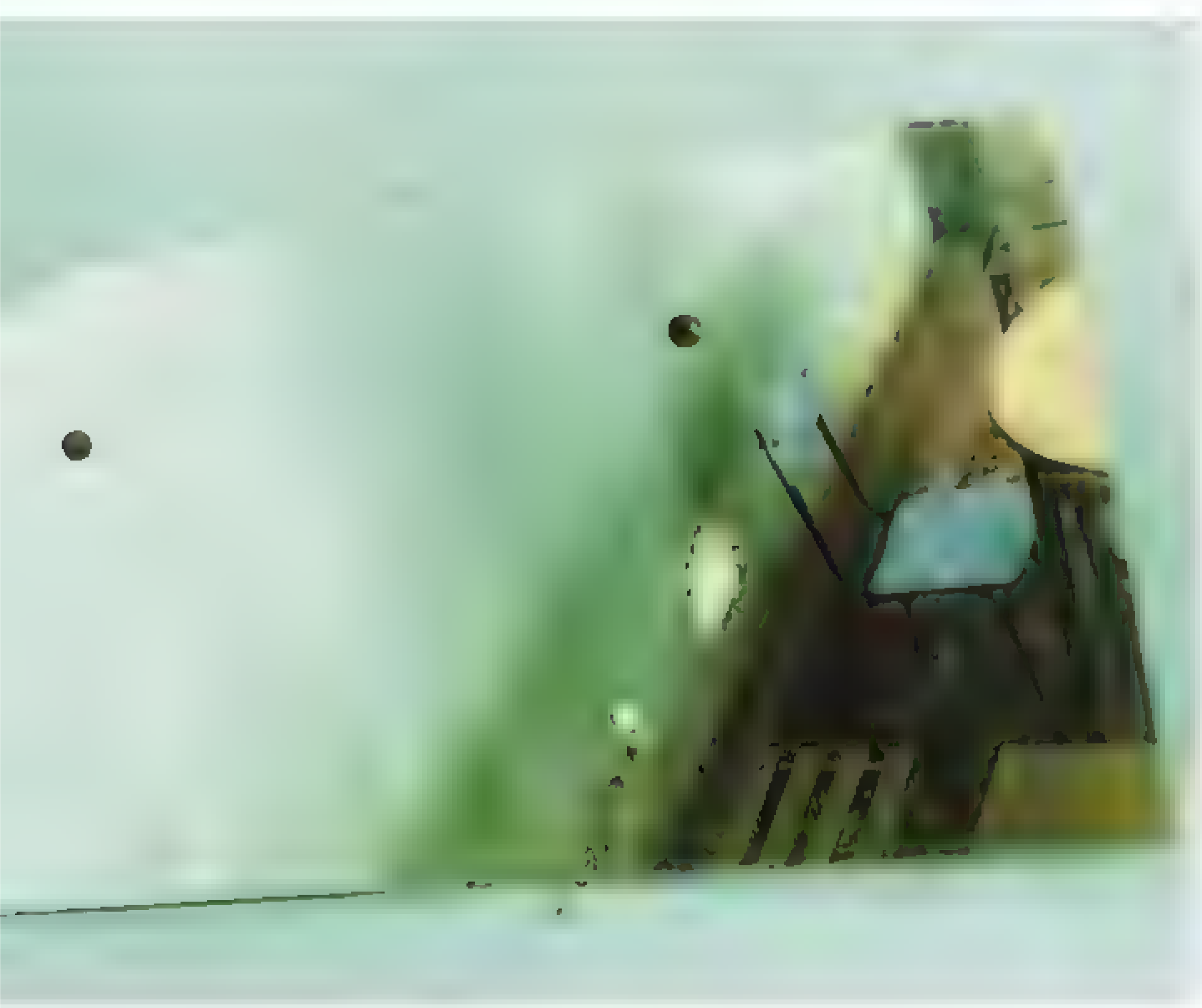
▲ figure 23
diffuse reflection and mirror reflection

If sunlight falls on a sheet of white paper or a mirror, more than 90 per cent of the light is reflected. The reflection from the sheet of white paper is diffuse: the reflected sunlight goes in all directions. The light reflected from a mirror, however, bounces back in very specific directions. This is why you can see your face in a mirror but not in a sheet of white paper.

Mirrors Experiment 4

A **mirror** consists of a sheet of glass onto which a thin layer of aluminium or silver has been applied. Light passes through the glass and is then reflected by the layer of metal underneath. Because the metal surface is extremely smooth and flat, you get a **mirror reflection:** the light bounces off, but does not do so in all directions as it does in diffuse reflection (figure 23).

If you look in a plane (flat) mirror, you see your **mirror image** 'behind' the mirror (figure 24). The mirror image even has depth: it really does appear to be behind the mirror. When you are holding a mirror, look first at your hand and then at the image of your face. You can feel your eyes having to adjust. The mirror image is further away than your hand.

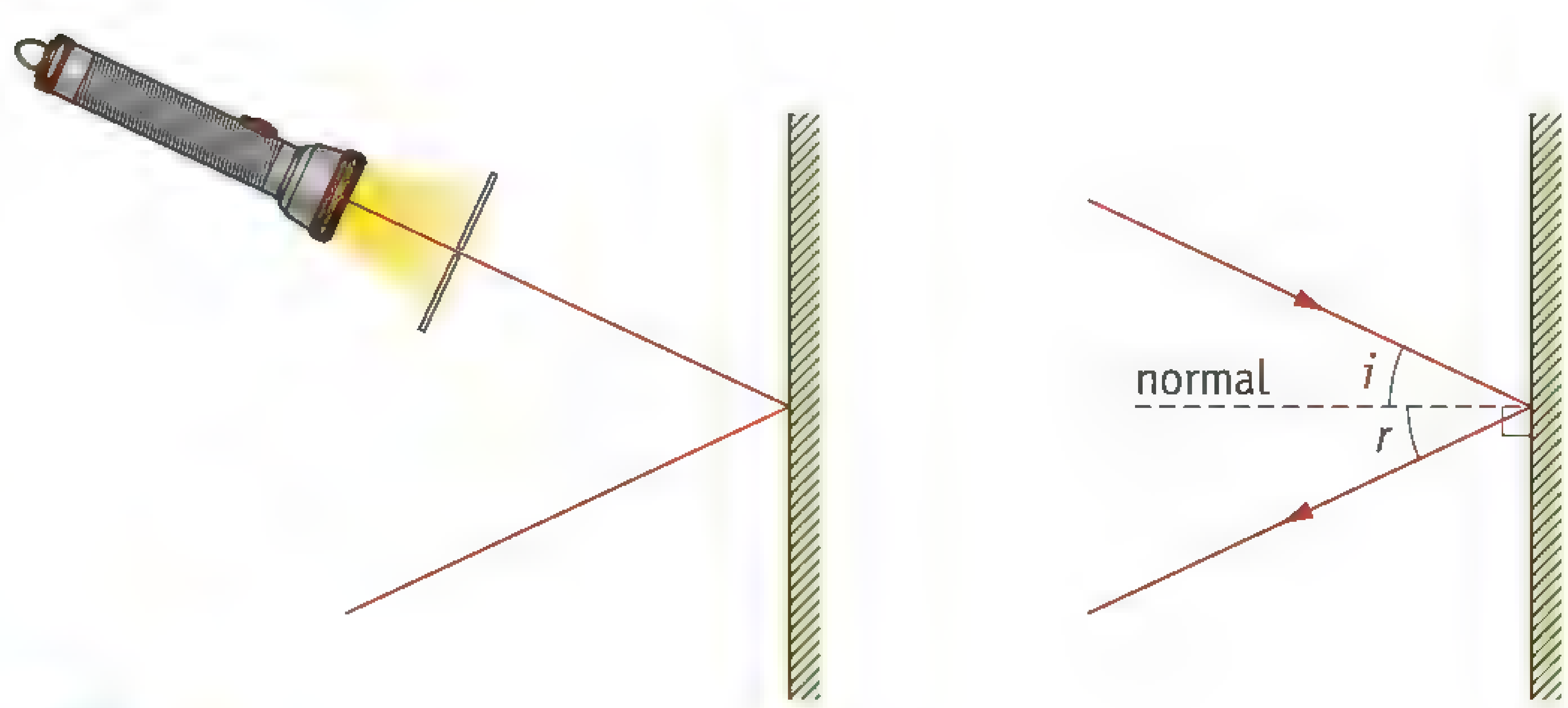


▲ figure 24
It seems as if there is another world behind the glass, where everything is mirror images.

There is a striking difference between the 'mirror world' and the world in front of the mirror: back and front are reversed. You notice that if you look at a text in the mirror. You then see that the text is in **mirror writing** (just like when you hold a piece of paper up to the light and try to read the text through it from the back). The opposite is true as well: if you hold mirror writing up to a mirror, the letters then look normal again.

The law of reflection Experiment 5

The drawing in figure 25 shows you how a plane mirror reflects a narrow, parallel beam of light. Because you can draw that beam of light as a single ray of light, we generally do say 'ray' for short rather than 'narrow, parallel beam of light'.



▶ figure 25
This is how light is reflected from a mirror.

A line has been drawn at the point where the ray hits the mirror, at right angles to the mirror: this is called the **normal** or perpendicular. The angle between the incoming ray and the normal is called the **angle of incidence** ($\angle i$). The angle between the reflected ray and the normal is called the **angle of reflection** ($\angle r$).

When a mirror reflects light, the rule is always that

the angle of incidence = the angle of reflection,

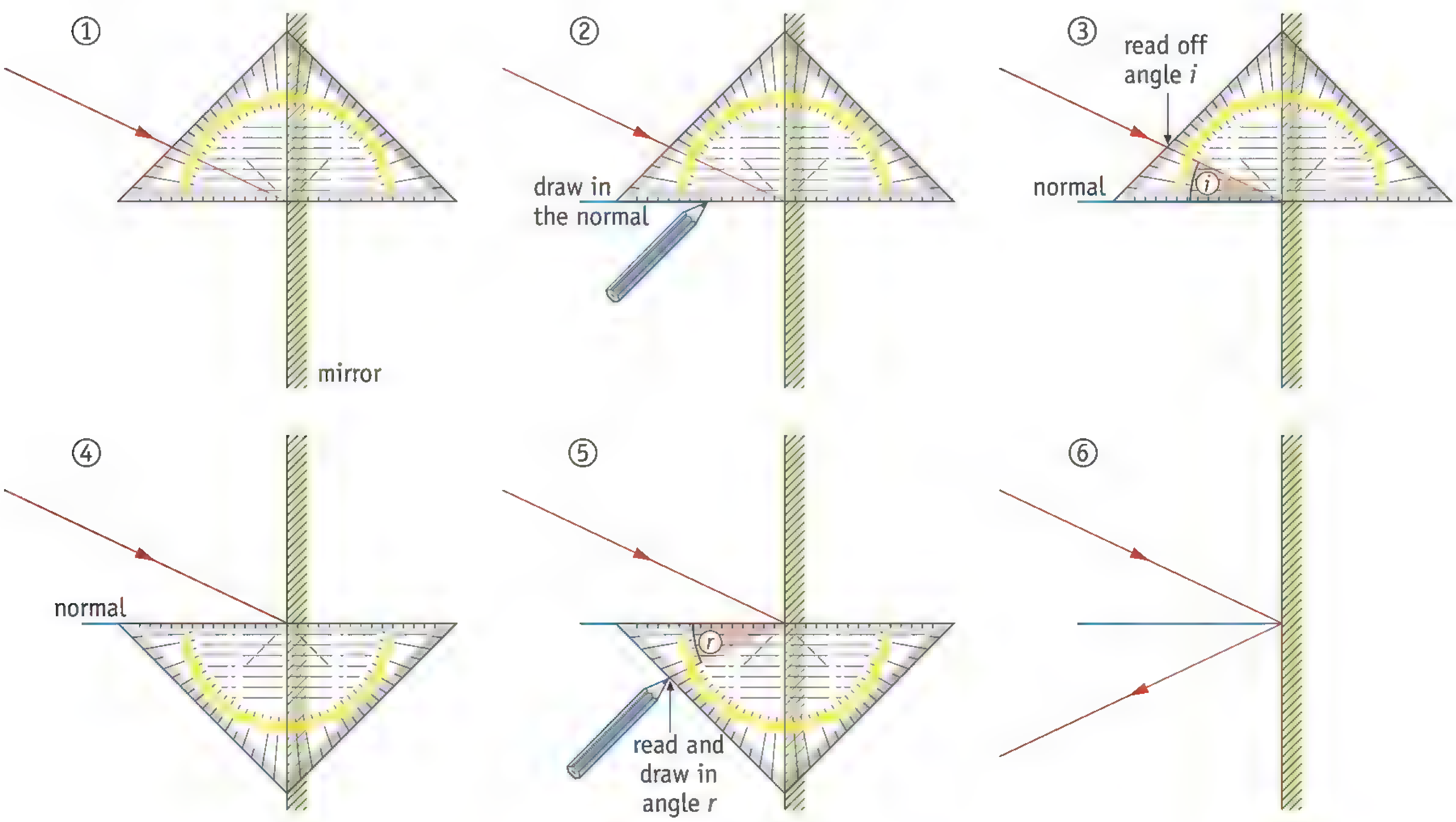
or in symbols:

$\angle i = \angle r$

This rule is known as the **law of reflection.**

You can use the law of reflection to draw how a ray is reflected by the mirror (figure 26):
1 Place your protractor as shown in the drawing.
2 Draw in the normal.
3 Read off the angle.
4 Now put your protractor on the other side of the normal.
5 Apply the law of reflection and mark in the angle of reflection.
6 Draw in the reflected ray.

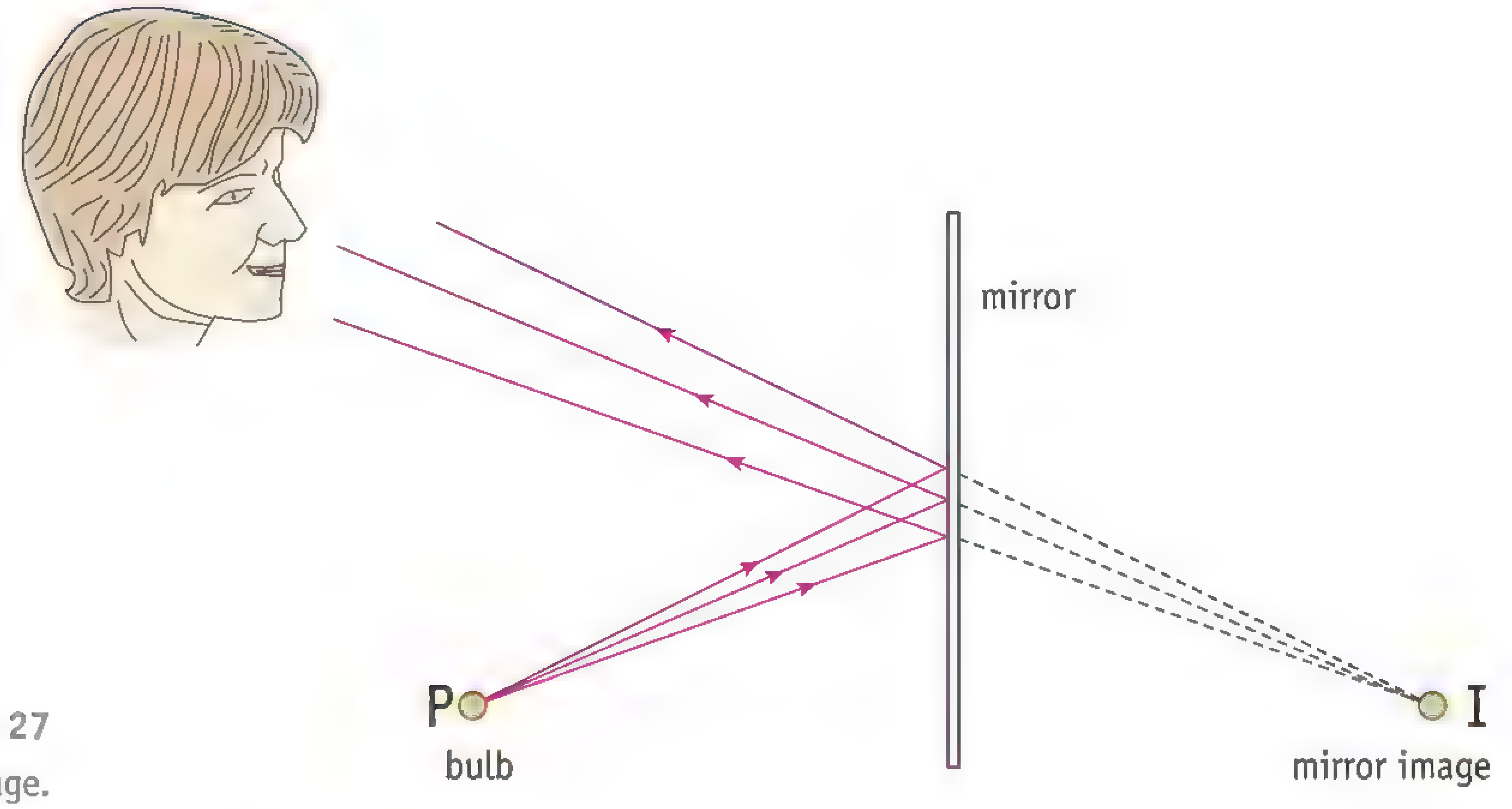
▼ **figure 26**
How to draw in the reflected ray using the law of reflection.



Drawing the mirror image

Experiment 6

Figure 27 shows a bulb that is in front of a mirror. The reflected rays seem to come from a point that is behind the mirror. If you look into the mirror, that is where you will see the mirror image of the bulb.



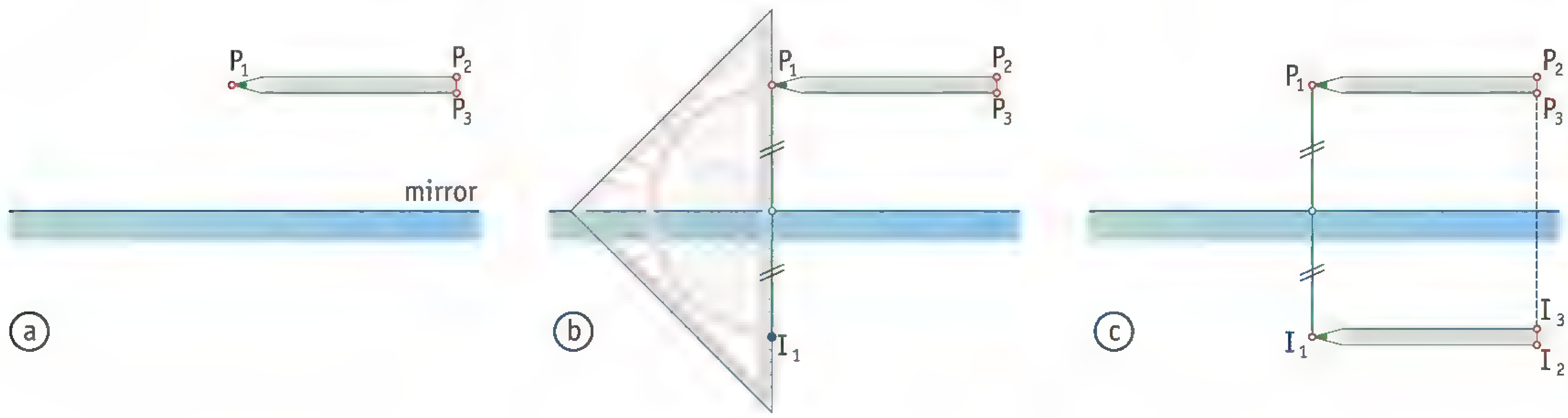
▶ figure 27
Looking at a mirror image.

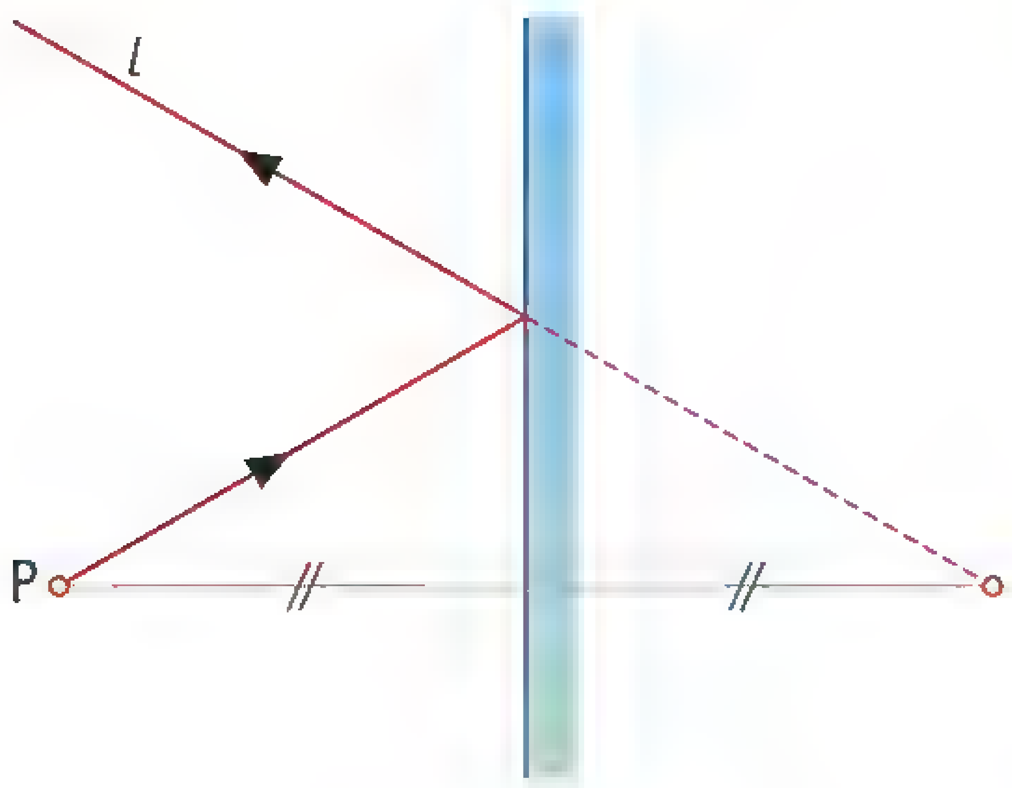
The mirror image is as far behind the mirror as the object is in front of it. You can find the location of the mirror image as follows (figure 28):

1 Select a random point P on the object.
2 Place your drafting protractor as shown in the drawing.
3 Draw in an image point I, such that I is as far behind the mirror as P is in front of it.

You can use this method to determine the mirror image of every point on the object. Number the points of the object P_1, P_2, P_3 and so forth. Number the points of the image I_1, I_2, I_3 and so forth. If a point is not directly in front of the mirror, you may extend the line of the mirror in the drawing in order to let you find the image point.

▼ figure 28
How to draw the mirror image of an object.





▲ figure 29
How to draw in the reflected ray using the image point.

Drawing in the reflected ray

If you want to draw how a mirror reflects the light from source P, you do not have to use the law of reflection. It is usually simpler to start by drawing the image point I for the light source. You can then use the fact that the reflected rays appear to come from point I.

Figure 29 shows you a drawing in which a random ray is reflected by a mirror. To make this kind of drawing, you first mark in the image point for P. This is point I. Then you draw the line *r* starting from I, first as a dashed line behind the mirror, then as a solid line in front of the mirror. The solid part in front of the mirror is the reflected ray.

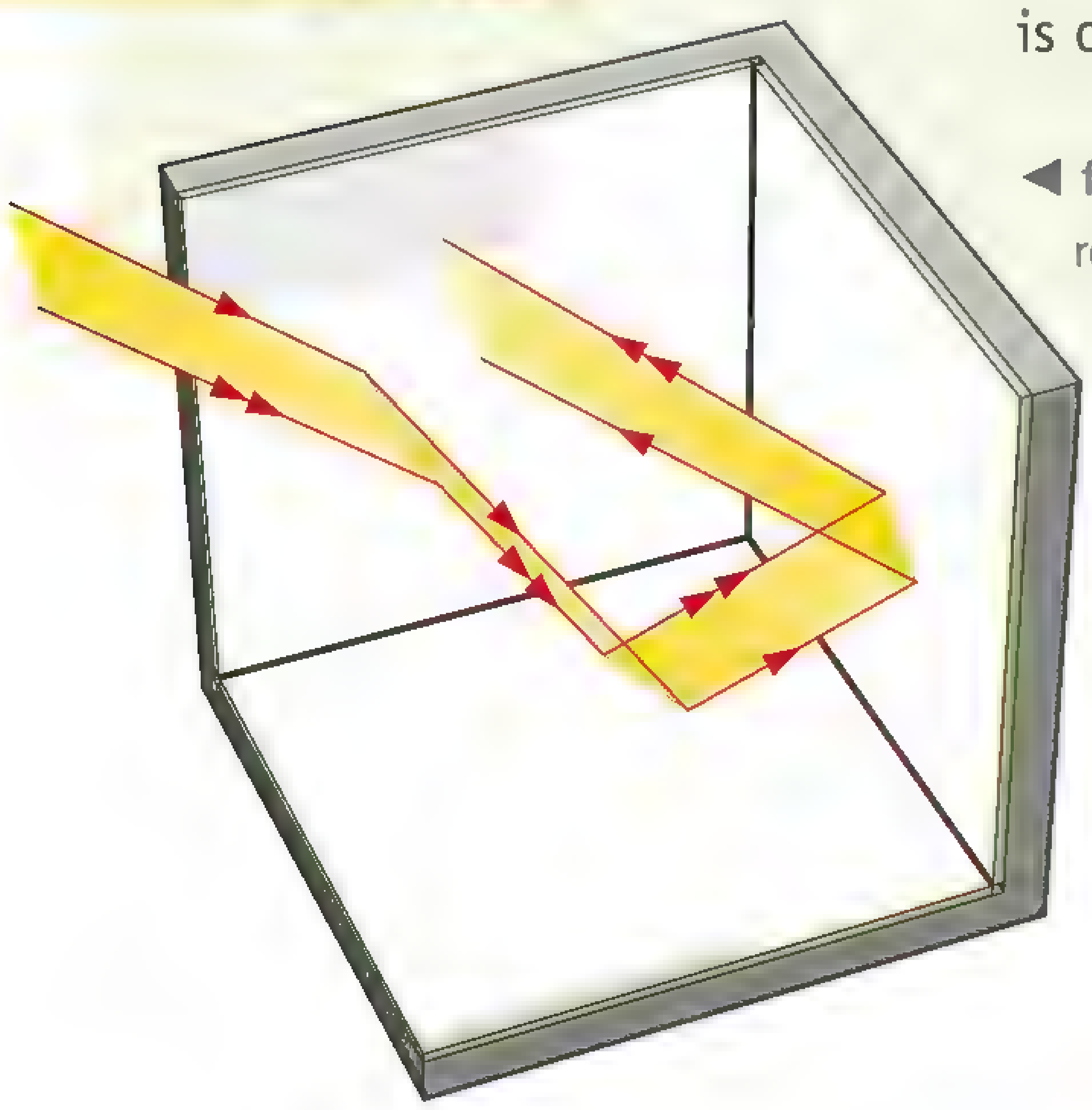
▼ figure 30
an image in a corner cube mirror

Plus Reflectors

The man in figure 30 is looking into what is known as a **corner cube mirror.** This consists of three mirrors that are each perpendicular to the other two. When you look into a corner cube mirror, you see your face upside down. If you move your head from left to right, the mirror image goes the other way.

You can use a narrow beam of light to investigate how light is reflected from a corner cube mirror. You then see that a beam of light that goes into the corner cube mirror is reflected three times, once by each mirror. The net result is that the direction of the beam of light is precisely reversed: the light goes back in the direction it came from (figure 31).

Corner cube mirrors are used in **reflectors.** A reflector on a bicycle may, for example, be made of a large number of very small corner cube mirrors. If a car's headlights shine on the reflector, the light is reflected back in the direction of the car. The driver therefore gets a warning that a cyclist is on the road ahead of him.



◀ figure 31
reflection in a corner cube mirror

Exercises

26 Make a drawing of a ray that is reflected by a plane mirror. Note in your drawing:
- **a** the direction in which the ray is going.
- **b** which line is the normal.
- **c** what the angle of incidence is.
- **d** what the angle of reflection is.

27 Answer the questions below.
- **a** What is the difference between mirror reflection and diffuse reflection?
- **b** How can you see that the mirror image appears to be behind the mirror?
- **c** What problem do you encounter if you try to read a piece of text in a mirror?
- **d** Point P is 4.5 cm in front of a mirror. Where do you draw the image point I?

28 The text on a barber's shop window says BARBER as seen from the street. How does this word appear to one of the barber's customers:
- **a** if he is looking directly out through the window?
- **b** if he is looking out through the window via the barber's mirror?

29 You need worksheet 8-4 for this exercise.
In figures (a) to (e) on the worksheet, draw in:
- **a** the normal, at the correct position.
- **b** the reflected ray.

30 You need worksheet 8-5 for this exercise.
A beam of light from a pocket torch hits a mirror.
Draw in how the beam of light is reflected.

***31** You need worksheet 8-6 for this exercise.
A solar energy plant consists of a large number of plane mirrors that are intended to reflect sunlight into an oven. The mirrors are on poles. You can see the oven, three poles (the mirrors have not yet been drawn) and the direction of the sunlight.
Draw the orientations on the worksheet for positioning the mirrors so that the light from the Sun is reflected into the middle of the oven.

***32** Look at the photograph of the sunset in figure 32.
Explain:
- **a** how the narrow strip of light appears that you can see running across the water.
- **b** why that strip of light always appears to be coming straight towards the observer.
- **c** what causes the darker stripes that interrupt the strip of light.

▲ figure 32
a reflected sunset

33 Continuation of exercise 32.
Just occasionally, you can see the mirror image of the setting Sun in the sea, instead of a strip of light such as that shown in figure 32.
a What is needed for you to be able to see a perfectly reflected, round disc of the Sun?
b Why are you more likely to be able to see this in a lake than in the sea?

34 You need worksheet 8-7 for this exercise.
Harry is looking at himself in a mirror.
a Draw the image points:
– of the top of his head (P_1).
– of his right eye (P_2).
– of the tip of his nose (P_3).
– of his chin (P_4).
b Now draw the mirror image of his face.

35 You need worksheet 8-8 for this exercise.
Miriam and Liz are standing in front of a large, reflecting shop window. The situation has been drawn from above on the worksheet.
Make an accurate drawing that shows clearly whether they can see each other in the window.

Plus Reflectors

36 Have a look at the cyclist in figure 33.
a Is the cyclist (including his bicycle) a direct light source?
b When does the cyclist become an indirect light source?
c Car drivers can see the cyclist better if he is wearing light-coloured clothing.
Explain why.
d What happens to the light that falls on dark clothing? Why is that less safe for the cyclist?
e The cyclist in figure 33 is wearing a jacket with reflecting strips. How do these strips reflect the light of a car: diffuse or mirror reflection? How can you see that?
f Why do reflecting strips like these improve safety?

▲ figure 33
Reflecting strips improve your safety.

37 What advantage does a reflector on the back mudguard of a bicycle have, compared to a normal mirror?

38 You need worksheet 8-9 for this exercise.
The worksheet shows a cross-section of the surface of a reflector.
A parallel beam of light hits the reflector.
Draw in how the light is reflected.

4 Infrared and ultraviolet

▲ figure 34
new-born goats under a heat lamp

The sun emits more than just light: it also produces infrared and ultraviolet radiation. These types of radiation are very similar to light. You do not notice them, however, because your eyes are not sensitive to them. That is not the case for all animals, though. Many birds, for example, can see very well in the ultraviolet.

Infrared radiation

All the objects around you – including humans and animals – are sources of **infrared (IR) radiation.** The higher the temperature of an object, the more radiation it emits. You will notice this if you hold your hand close to a hot radiator, for instance. You can feel that your hand is getting warm as it absorbs the infrared radiation from the radiator.

Heat lamps give off a little bit of red light that you can see, but primarily a lot of infrared. They are used a lot for keeping new-born animals warm (figure 34), but you also come across them as patio heaters and in infrared saunas. People and animals perceive the radiation emitted by these lamps as 'pleasantly warm'.

If you study the spectrum of a heat lamp, you will find the infrared radiation next to the red. To prove this, you can use a sensor that is sensitive to infrared. There are also infrared cameras that let you take photographs using infrared radiation. The name 'infrared' literally means 'below the red'.

▲ figure 35
a porch light with an infrared sensor

Applications of infrared

Infrared is also used for remote controls. The remote contains a LED that produces infrared radiation. When you press one of the buttons, the LED emits 'flashes' of infrared. This signal is picked up by an infrared sensor in the device, and it can then be processed by the electronics.

Infrared radiation is also used in automatic switches. The sensor in a porch light, for example, responds to infrared radiation emitted by people walking by. The sensor then switches on the current so that the lamp is turned on (figure 35).

You also find infrared sensors in alarm installations and in shop doors that open and close automatically. The military use night vision goggles that convert invisible infrared radiation into visible light.

▲ figure 36
A cap protects the sensitive skin of the face against UV radiation.

Ultraviolet radiation

When you lie in the sun your skin receives **ultraviolet (UV) radiation** as well as light. You skin responds to that by producing additional pigment: you get a tan. The pigment that gives you a tan has a protective effect. This is why you can stay in the sun for longer once your skin has darkened a bit.

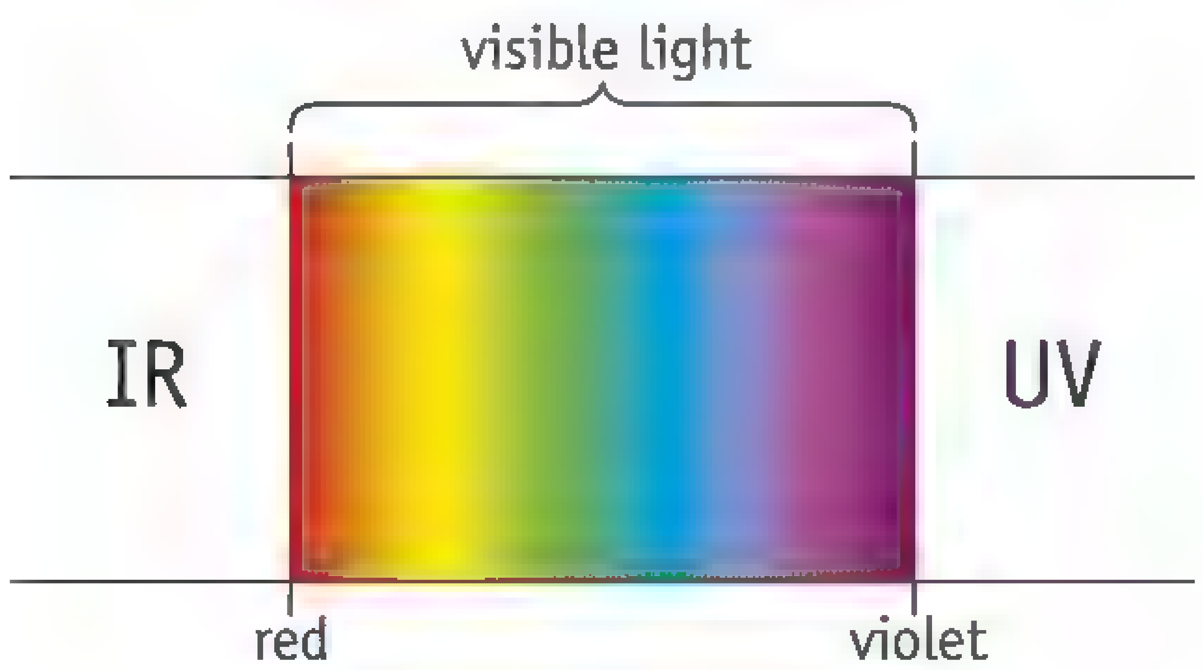
If you get too much ultraviolet radiation on your skin, you may get sunburnt. Your skin then becomes red and painful. This is a sign that your skin cells have been damaged. This is not only uncomfortable, but is also a health risk: too much ultraviolet increases the risk of skin cancer. This is why people are asked to be sensible in the sun (figure 36).

Sun cream contains a UV filter that blocks out some of the ultraviolet radiation. When you use sun cream, you get sunburnt less quickly. The packaging states the **protection factor.** This number states how many times longer you can stay in the sun. A cream with factor 10, for instance, means you can sunbathe for ten times as long. If you would be able to sunbathe for 5 minutes without a cream, you would be able to have $10 \times 5 = 50$ minutes with this cream.

UV lamps

There are also lamps that produce primarily ultraviolet, such as the **UV lamps** in a solarium or blacklights in discos. As well as ultraviolet radiation, these lamps do produce a bit of violet light. You can recognise UV lamps and blacklights by this violet light.

If you study the spectrum of a UV lamp, you will find the ultraviolet radiation next to the violet. You can show this by measuring the amount of ultraviolet radiation using a UV sensor. The name 'ultraviolet' literally means 'beyond the violet'.



▶ figure 37
Where infrared and ultraviolet are in the spectrum.

Experiment 7

Ultraviolet radiation can make some substances light up brightly. This is known as **fluorescence**. Fluorescent materials are used in fluorescent tubes and banknotes, among other things. Under a UV lamp, the fluorescent ink in a genuine banknote lights up clearly; a forgery that does not use fluorescent ink will not do that (figure 38).

▶ **figure 38**
Banknotes being checked under a UV lamp.

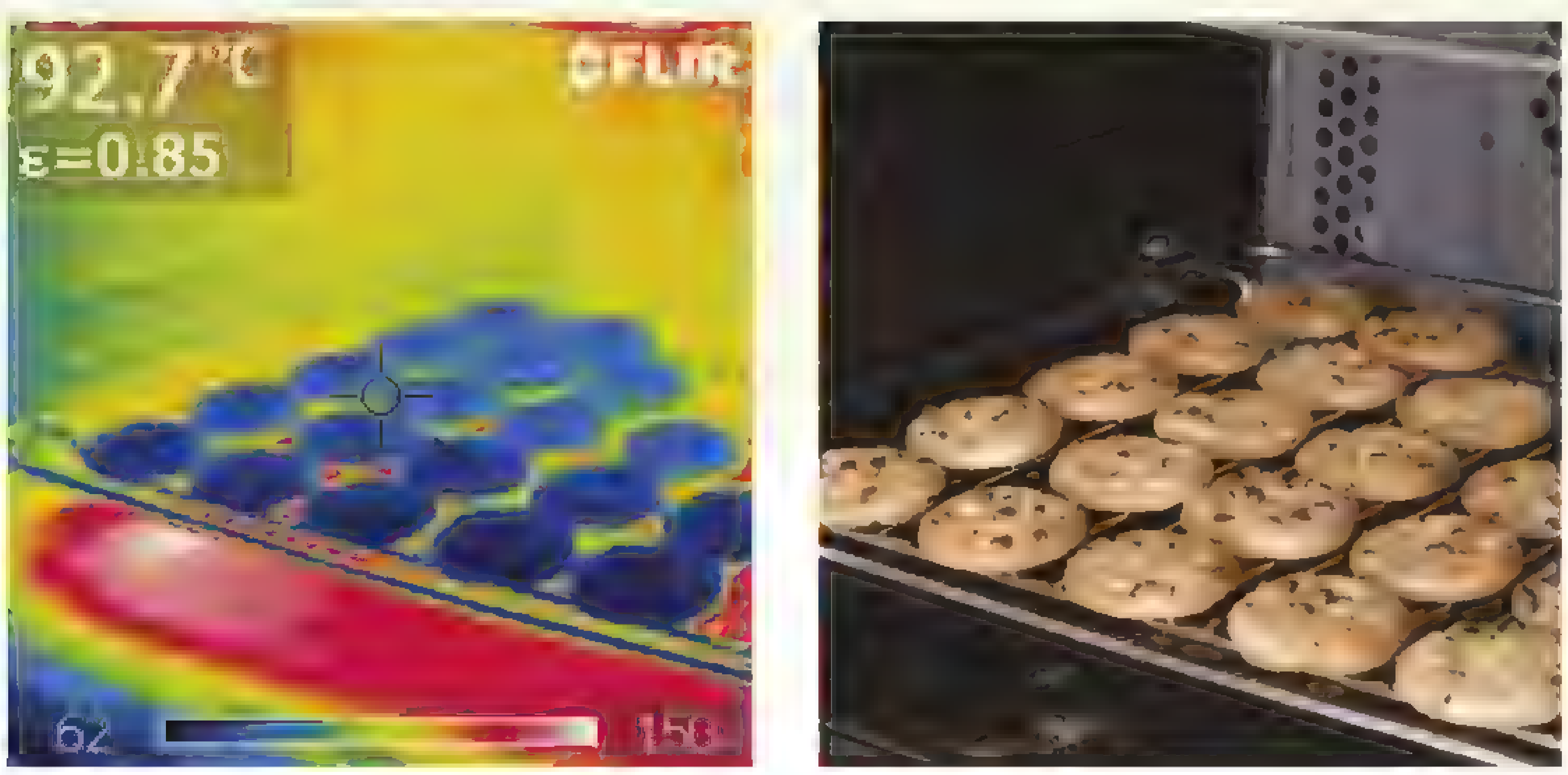
Plus The infrared camera

An infrared camera looks like any other camera. You take photos with it in the same way. The difference is that the chip in an infrared camera is not sensitive to light, but instead detects infrared radiation. You can use it to make thermograms: photographs that show the differences in temperature in different parts of the scene being photographed (figure 39).

A **thermogram** is an example of what is known as a 'false colour' image. The colours in this type of picture are used to give information, rather than to record the actual colours. The colours in a thermogram give information about the temperature, based on the amounts of infrared radiation emitted.

In order to be able to 'read' a thermogram, you need a scale that shows you what temperature is associated with which colour. The temperature scale in figure 39 goes from 62 °C (blue) to 150 °C (red). The designers of the camera chose those colours. There are also thermograms in which the highest temperature is shown as white.

▼ **figure 39**
a thermogram and a normal photo

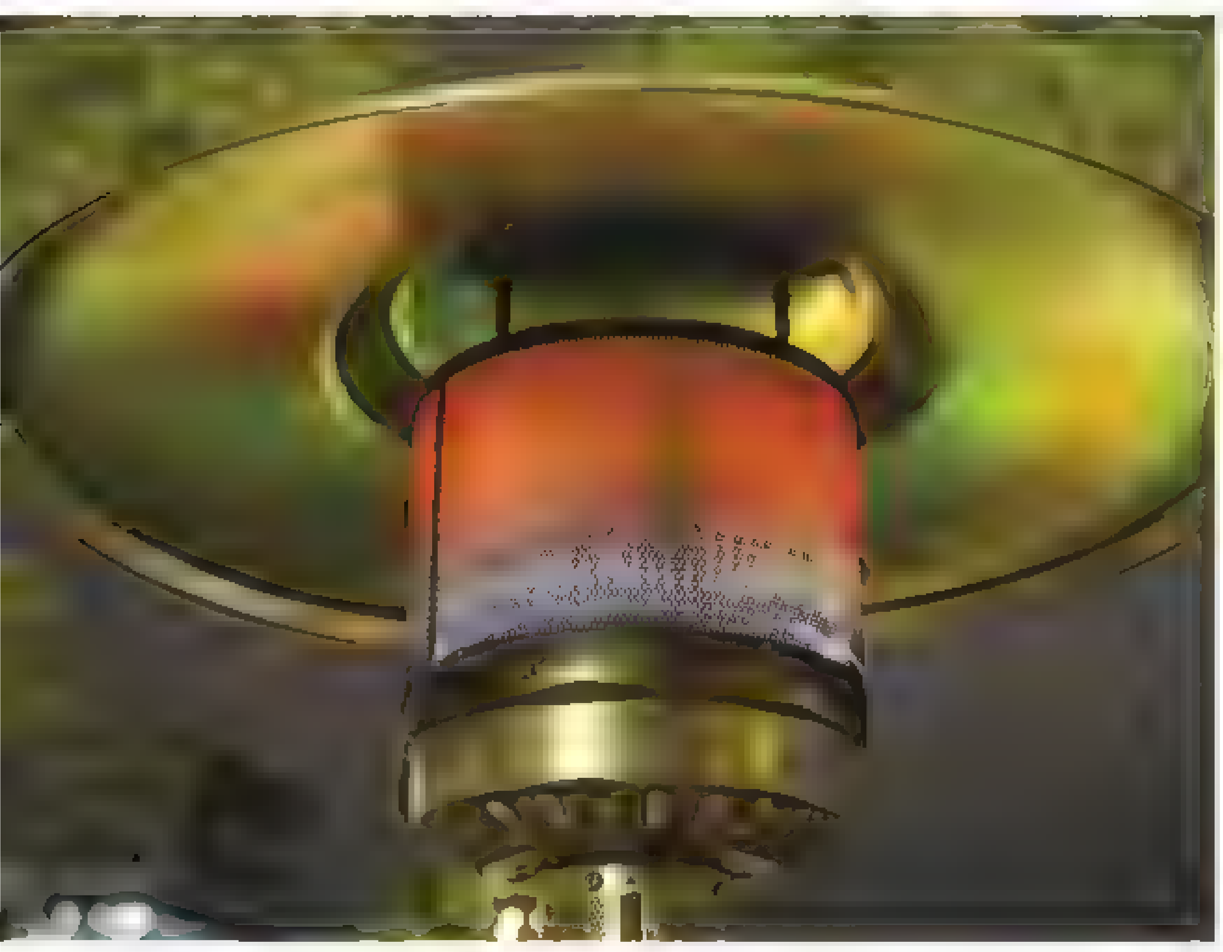


Exercises

39 Answer the questions below.
- a How can you tell that a hot radiator is emitting infrared radiation?
- b How does a remote control pass your commands to the device?
- c What type of radiation do UV lamps emit, in addition to a lot of ultraviolet?
- d What do you see when a fluorescent material is illuminated by ultraviolet radiation?

40 You can use a prism to split the radiation from the Sun to create a spectrum.
- a Draw a diagram to show the spectrum of sunlight with the various colours in their correct places.
- b Indicate where you can find the Sun's ultraviolet and infrared radiation in this spectrum.

41 Four sources of infrared or ultraviolet are listed below.
Which sort of radiation (IR or UV) is emitted by:
- a a blacklight?
- b a patio heater?
- c a heat lamp?
- d a sunbed?



▲ figure 40
Thanks to the patio heating, you can sit outside comfortably.

42 If the patio heating is on, people sitting outside are not affected by the cold (figure 40). The heating elements have caps around them with a reflective interior.
- a What does the inside of the cap have to reflect?
- b What goes wrong if the element does not have a cap like this?

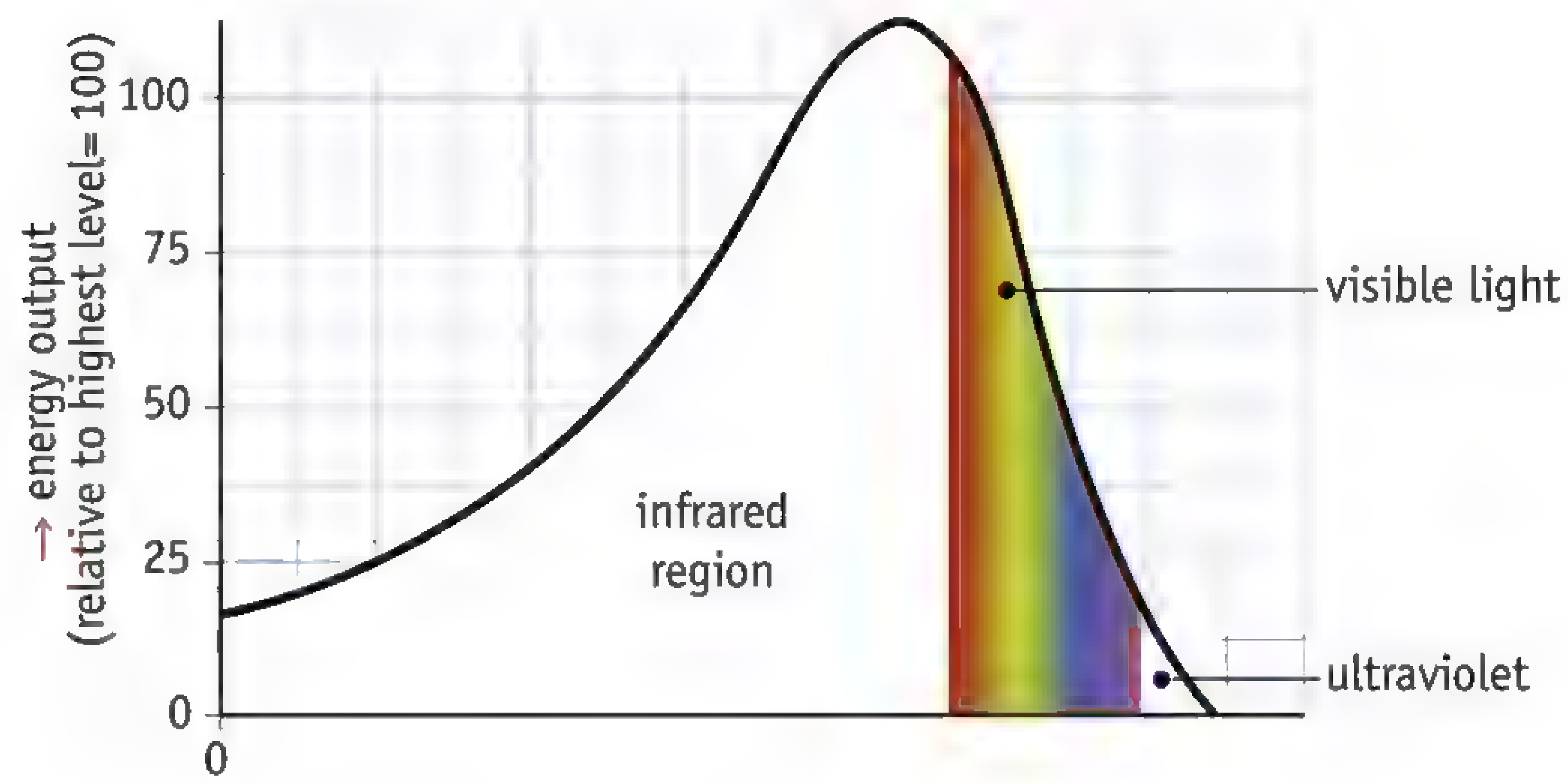
43 People, animals and objects get warmer when they absorb infrared radiation.
Explain why:
- a people gathered round a camp fire feel the warmth on their faces, while their backs remain cold.
- b a chicken under a grill has to be turned over regularly if it is to be browned evenly all over.
- c moving your chair back a metre helps if you are uncomfortably hot when close to an open hearth.

*44 An incandescent bulb converts electrical energy into various sorts of radiation. Figure 41 shows you how the energy consumed is distributed across the various types of radiation emitted.

a What shows you that an incandescent bulb is not very energy-efficient?

b Sketch what the graph would look like for a perfectly efficient bulb.

c Energy-saving lamps and LED lights are much more efficient in the way they use energy.
Explain how you can feel that if you put your hand close to these types of lights.



▶ figure 41
the composition of the radiation from an incandescent light bulb

▲ figure 42
welder with a welding hood

45 Welders wear welding hoods (figure 42). The glass in these helmets absorbs infrared, visible light and ultraviolet.

a Suppose that the welder did not wear a hood.
Which type of radiation would then:
- be too blinding for the welder while doing the work?
- permanently damage the welder's eyes?
- make the welder's face very hot?

b Which type of radiation must not be completely blocked?

c What would otherwise go wrong?

*46 A manufacturer of sun-tan oil has produced a rotatable disc giving times for unprotected tanning (UT), the recommended protection factor (RPF) and the maximum protected tanning time (PTT) for various different skin types (I, II and III). See table 1. The protection factor indicates how many times longer you can stay in the sun when the oil is used than you could if you were unprotected.
Copy the table and fill in the missing numbers.

▼ table 2 tanning table

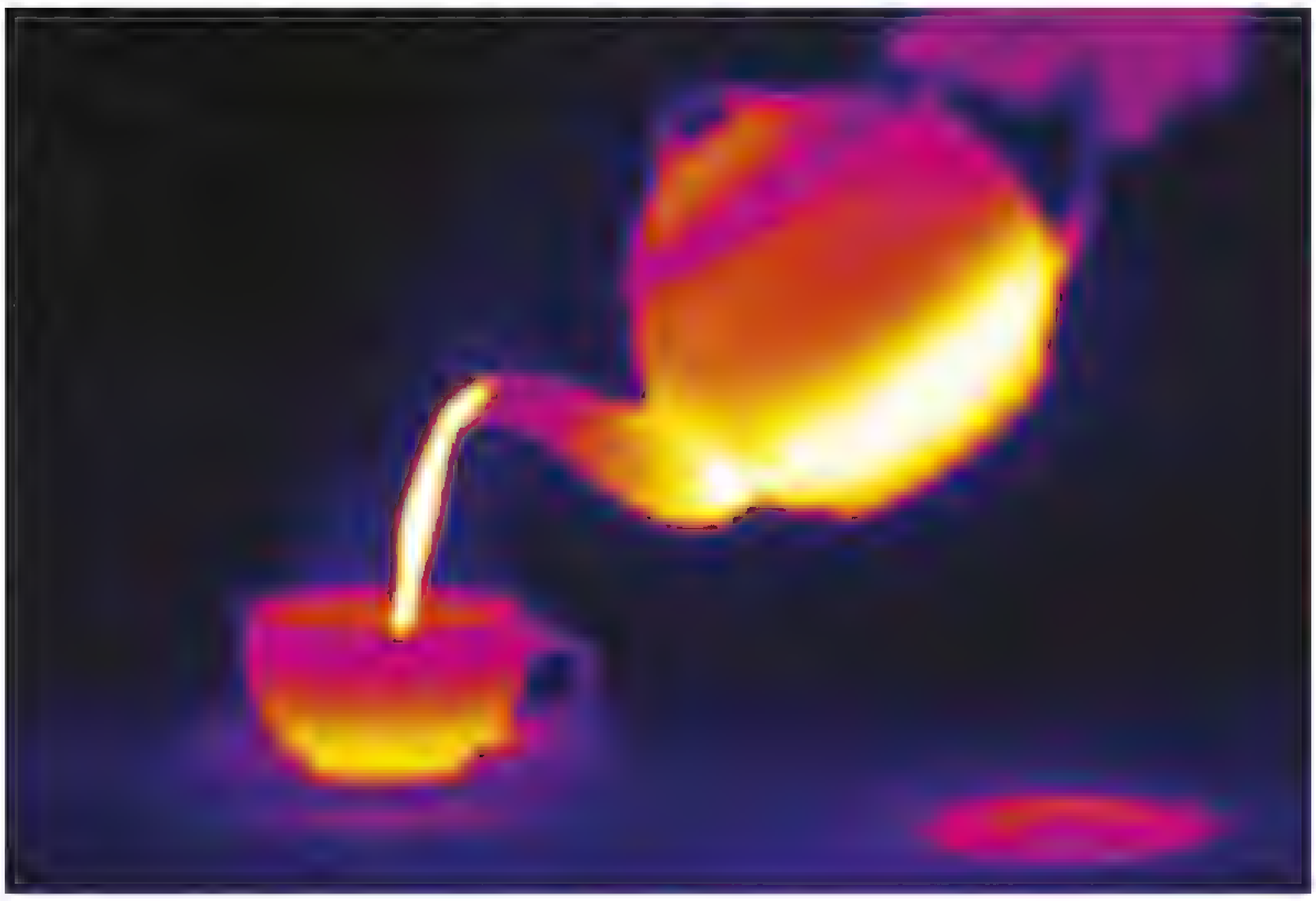
skin type	I	II	III
UT (in min)	15		25
RPF	20	12	
PTT (in min)		300	200

47 Search the Internet for information about snow blindness.
- **a** What is snow blindness and what causes it?
- **b** Why are people doing winter sports particularly affected by it?
- **c** Why is there not much risk of snow blindness in the Netherlands?
- **d** What should you do to protect yourself against snow blindness?

Plus The infrared camera

48 Answer the questions below.
- **a** Why is a thermogram a type of false colour image?
- **b** What information can you derive from the colours in a thermogram?
- **c** What do you need in order to be able to interpret a thermogram correctly?

49 Study the thermogram in figure 43.
- **a** Which colour gives the highest temperature?
- **b** Which colour gives the lowest temperature?
- **c** How can you see that the tea is very hot?
- **d** Which part of the teapot is hottest? Why is that?
- **e** The teapot had been put down first at the right of the table. Why can you now still see a 'thermal shadow' there?



▶ **figure 43**
a thermogram of tea being poured

***50** Explain why:
- **a** people in a thermogram that has been taken at night stand out clearly against their surroundings.
- **b** you can often use a thermogram to trace a leak in underfloor heating pipes very quickly.
- **c** a foot with poor blood circulation looks different on a thermogram to a healthy foot.

Experiments

Experiment 1 Making a spectroscope 20 min

Introduction
If a shower of rain passes over on a sunny day you can sometimes see a rainbow. The Sun is then shining through water droplets that split up the sunlight into various different colours. You can also use a spectroscope to split up white light into its various component colours.

Aim
In this experiment you are going to make a simple spectroscope yourself using a piece of diffraction foil.

Requirements
- piece of diffraction foil
- strip of cardboard
- sticky tape
- hole punch

Note: one side of the diffraction foil (the side with a slight haze) is very fragile. Do not touch this side with your fingers.

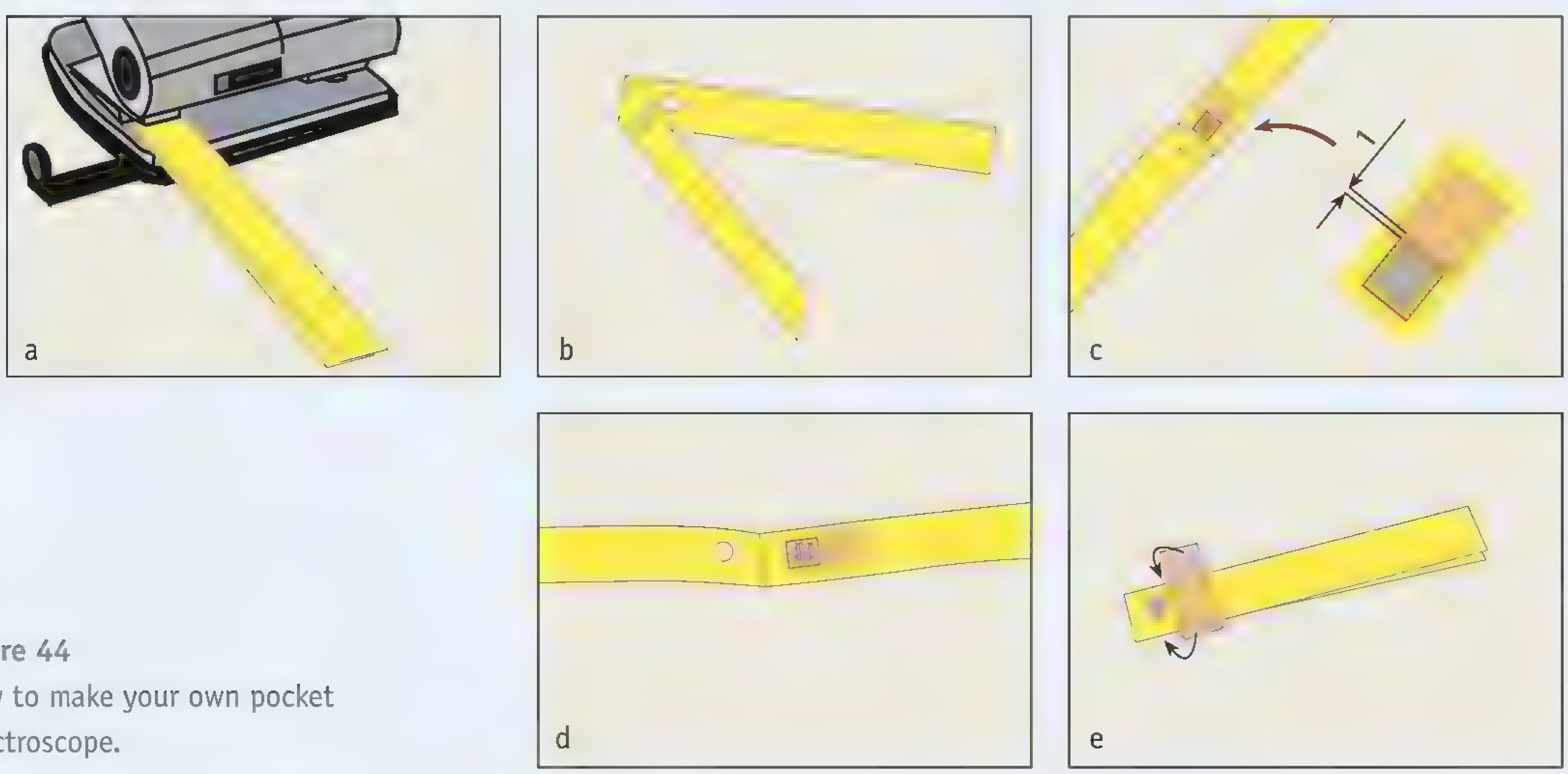
Doing the experiment and writing it up
Making a spectroscope
- Fold the strip of cardboard double (one end against the other).
- Push the fold into the hole punch (figure 44a).
- Make a hole close to the fold (figure 44b).
- Tear off a small piece of sticky tape and stick it onto the edge of the diffraction foil (with about 1 mm overlap).
- Use the sticky tape to place the diffraction foil over one of the holes in the cardboard strip (figure 44c)
- Press the sticky tape firmly in place to hold the diffraction foil in position (figure 44d).
- Fold the strip double again. Use another piece of sticky tape to hold the strips together just below the perforation (figure 44e).

Using a spectroscope
- Hold the spectroscope in front of one eye and look just next to a light source. You can then see the colours that make up the light source.
- Look outside through the spectroscope (but NOT in the direction of the Sun!)

1 What colours are there in daylight?

- Look through the spectroscope at various sources of white light.

2 Does the light from these sources have the same composition as sunlight? How can you see that?



▲ figure 44
How to make your own pocket spectroscope.

Experiment 2 Spectra of lamps 30 min

Introduction
The light from a lamp consists of different colours. If you look at the light of a lamp through a spectroscope, you see the various colours next to one another. A series of colours like this is called the spectrum of the light.

Aim
In this experiment, you are going to be investigating the spectra of various lights.

Requirements
- pocket spectroscope
- fluorescent tube
- low-pressure sodium lamp (SOX)
- energy-saving lamp
- halogen lamp
- mercury lamp
- coloured pencils

Doing the experiment and writing it up
– Use the spectroscope to look at the spectra of the various lamps.

1 Use the coloured pencils to draw the spectra of the lamps.
2 Which lamp only emits a single colour of light?

Experiment 3 Umbra and penumbra 15 min

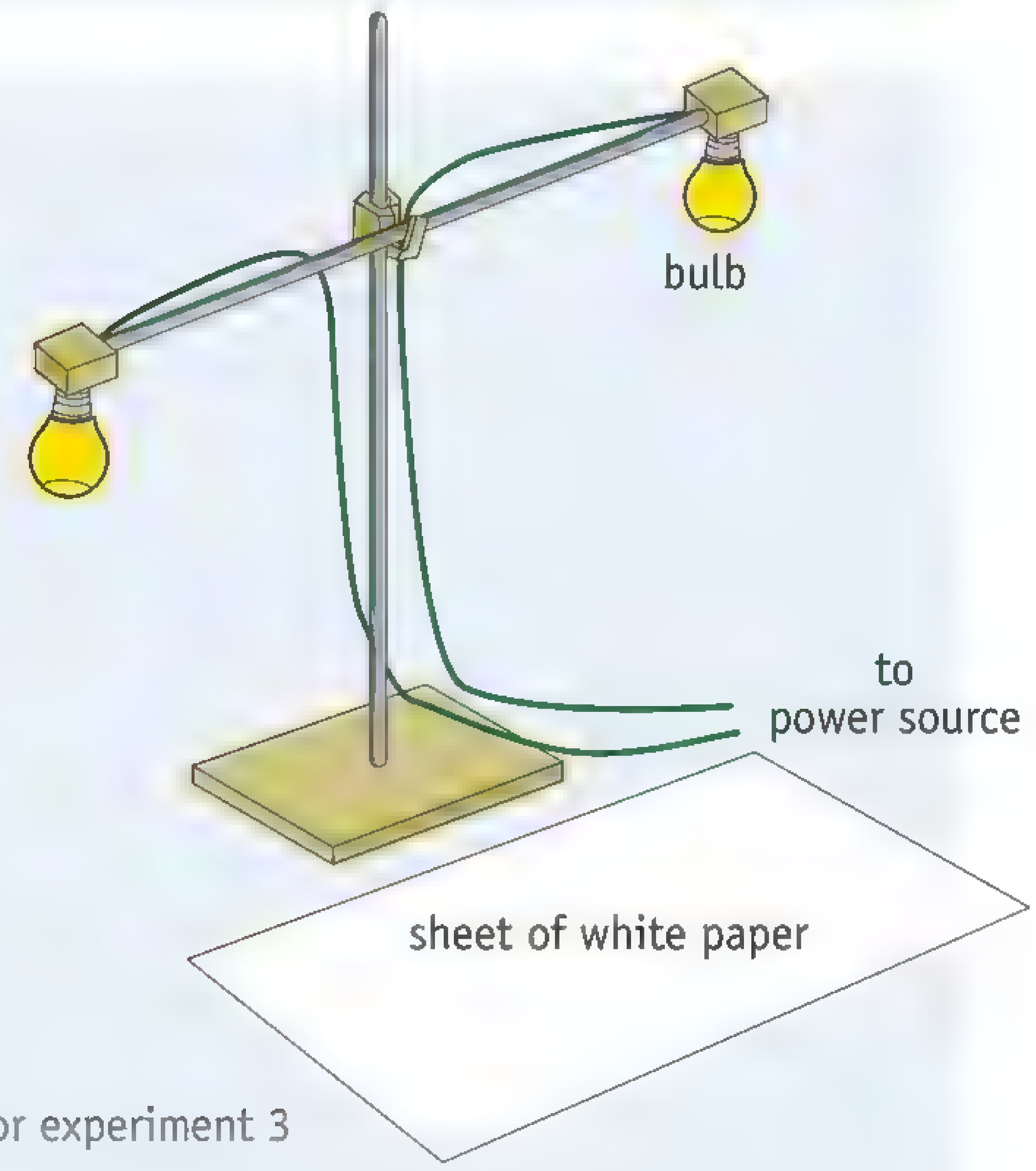
Introduction
Having two lamps above a table-top gives different shadows from those of a single lamp. You can then often see a dark 'core' shadow (umbra) between two lighter half-shadow areas (penumbra).

Aim
In this experiment, you are going to be investigating how you can produce an umbra and a penumbra.

Requirements
- retort stand with clamps
- two bulbs
- voltage source
- wires
- square piece of cardboard
- sheet of white paper

Doing the experiment and writing it up
– Set the experiment as show in figure 45.
– Hold the square of card between the bulbs and the sheet of white paper. Move the piece of card up and down.

1 Describe how you see the shadows change:
  a as you move the card upwards, towards the bulbs.
  b as you move the card downwards, towards the paper.



▶ figure 45
the setup for experiment 3

– Hold the piece of card so that you can see two light shadows next to each other, not overlapping. These are half shadows: penumbra.
– Unscrew the left-hand bulb so that it goes out.

2 Which half shadow disappears now? Why is that?

– Screw the left-hand bulb in again so that you have two partial shadows again. Now hold the card so that the two half shadows start to overlap.

3 What does the umbra (the core shadow area where the two half shadows overlap) look like?
4 Make a sketch in your exercise book of what these shadows look like. Write 'umbra' and 'penumbra' in at the appropriate places on your sketch.

Experiment 4 Looking at mirror images 15 min

Introduction
The mirror image of an object looks just like the object itself – or so you would say at first sight. But you soon see that there is something different about the mirror image if you look at letters in a mirror. A word that you could normally read fluently suddenly looks different.

Aim
You are going to investigate the difference between mirror images and reality.

Requirements
- mirror

Doing the experiment and writing it up
– Look at the person next to you in the mirror.

1 Can the person next to you see you in the mirror at the same time?

– A sentence has been written on the board in mirror writing. Look at the board in the mirror.

2 What does the sentence look like now?

– Write your name while looking at your hand holding the pen in the mirror.

3 Explain what makes this so difficult.

– Write your name in mirror writing without using the mirror.

4 Check the result in the mirror. Did you get it right?

5 Look at figure 46.
What word is written in mirror writing here?
6 Explain why mirror writing has been used here.

– Write the words 'STOP POLICE!' in mirror writing without using the mirror.

7 Check the result in the mirror. Did you get it right?
8 Where might you see this phrase in mirror writing, do you think?

▲ figure 46
a practical application of mirror writing

Experiment 5 The law of reflection 15 min

Introduction
You can use a small mirror to reflect the light of the Sun onto a wall. You then see a spot of light appear at a single place. If you move the mirror, the patch of light moves as well. Do you think you could predict where the sunlight will end up?

Aim
In this experiment, you investigate the direction that a mirror reflects light in.

Requirements
- mirror
- light box
- diaphragm with a single aperture
- worksheet 8-10

Doing the experiment and writing it up
– Take worksheet 8-10. Place the mirror at the position indicated.
– Place the diaphragm with a single opening in the light box.

– Direct a ray of light at the mirror, as shown on the worksheet. In this case, the angle of incidence is 30 degrees.

1 Copy table 3 into your exercise book.

– Determine the angle of reflection for each angle of incidence.

2 Note the results in the table.
3 What conclusion can you reach?

▼ **table 3** the measurement results for experiment 5

angle of incidence *i*	angle of reflection *r*
10°	
20°	
30°	
40°	
50°	
60°	
70°	
80°	

Experiment 6 The position of the mirror image 20 min

Introduction
The mirror image that is created by an object in front of a mirror is a virtual image (has no real presence).

Aim
You can however investigate exactly where this virtual image is located.

Requirements
- mirror + mirror holder
- worksheet 8-11

Doing the experiment and writing it up
– Take worksheet 8-11. Put the mirror at the position indicated in drawing (a), perpendicular to the paper.
– Draw a dot at the point where you see the mirror image of P_1 (you will have to squat or bend your knees for this). Write I_1 next to it.
– Do the same for point P_2, P_3 and P_4, labelling the image points I_2, I_3 and I_4 respectively.
– Join P_1 to I_1, P_2 to I_2 and so forth.

1 What can you say about where the mirror image is located?

– Look at drawing (b) on the worksheet. Use the mirror to help draw the mirror image of the various letters.

Experiment 7 Fluorescence 15 min

Introduction
If a UV lamp is shone onto a fluorescent material, the UV radiation is absorbed. Part of that absorbed radiation is then re-emitted as visible light: you can see the material 'light up'. A so-called 'blacklight' can be used as the UV lamp.

Aim
You are going to investigate how a blacklight works.

The question you are studying is:
What do banknotes, reflective strips on raincoats and highlighter pen inks look like when illuminated with UV light?

Requirements
- blacklight
- banknotes
- safety jacket with reflecting strips
- highlighter pen
- sheet of white paper
- partially blacked out room

Doing the experiment and writing it up
- Shine the blacklight onto various banknotes.

1 Where can you see fluorescence?
2 Describe what the fluorescence looks like.

- Shine the blacklight onto the sheet of white paper.

3 Is there any fluorescence now?
4 What does the paper look like?

- Draw a simple shape on the paper using the highlighter pen and look at it under the blacklight.

5 Is there any fluorescence now?
6 What does the figure you have drawn look like?

- Shine the blacklight onto the jacket with the reflecting strips.

7 Is there any fluorescence?
8 Describe what the jacket looks like now.

Experiment 8 Carrying out research: a shadow play 45 min

Introduction
Imagine: in a shadow play or shadow theatre, a story is told using shadow puppets (figure 47). The audience sits in front of a translucent screen and the actors are behind it. The screen is lit from behind by a lamp. The players hold up flat puppets (on sticks) in front of the light so that the shadows of the puppets appear on the screen. By moving the puppets back and forth, the shadows on the screen can be made larger or smaller. In this experiment, you are going to be investigating what the size of the shadow image depends on.


▲ figure 47
a shadow play

Aim
In this experiment, you are going to work out a way of predicting the size of a shadow beforehand.

Requirements
For this experiment you have to think up for yourself what equipment you will need.

Doing the experiment and writing it up
- Think about the ways you know for predicting the value of a variable. Which method are you going to use?
- Formulate the study question (or questions) that you want to answer in this investigation.
- Think how you are going to be able to provide a reliable answer to the study question. What are you going to measure, what items will you need for the experiment, and how are you going to process the measurements?

1 Make a work plan for this research.

- The work plans will be discussed with the rest of the class at the next lesson. If necessary, you can make improvements to your own work plan after that.
- Then carry out the experiment.

2 Note down all the measurements, calculations and results in your exercise book.

- Your teacher will tell you whether or not you have to write up a report on this experiment.

Test Yourself

You can also do questions 1 to 16 on the computer.

1 You can recognise types of lamp by the light that they produce.
State which word fits in the sentence. Choose between:
sodium lamp – energy-saving lamp – UV-lamp – heat lamp
a A ...... produces weak red light.
b A ...... produces bright yellow light.
c A ...... produces weak violet light.
d A ...... produces bright white light.

2 Which two cars will appear to be the same colour in the light of an SOX sodium lamp?
A a blue car and a yellow car
B a yellow car and a white car
C a white car and a red car
D a red car and a yellow car

3 Magnesium oxide is a pigment that is used in paint. This pigment reflects 98% of the sunlight that falls on it.
What colour is magnesium oxide?
A bright yellow
B bright red
C bright white
D deep black

4 A white car and a black car are in bright sunlight in a car park.
a Which car absorbs most of the sunlight?
b Which are reflects most of the sunlight?
c Which car gets hotter?

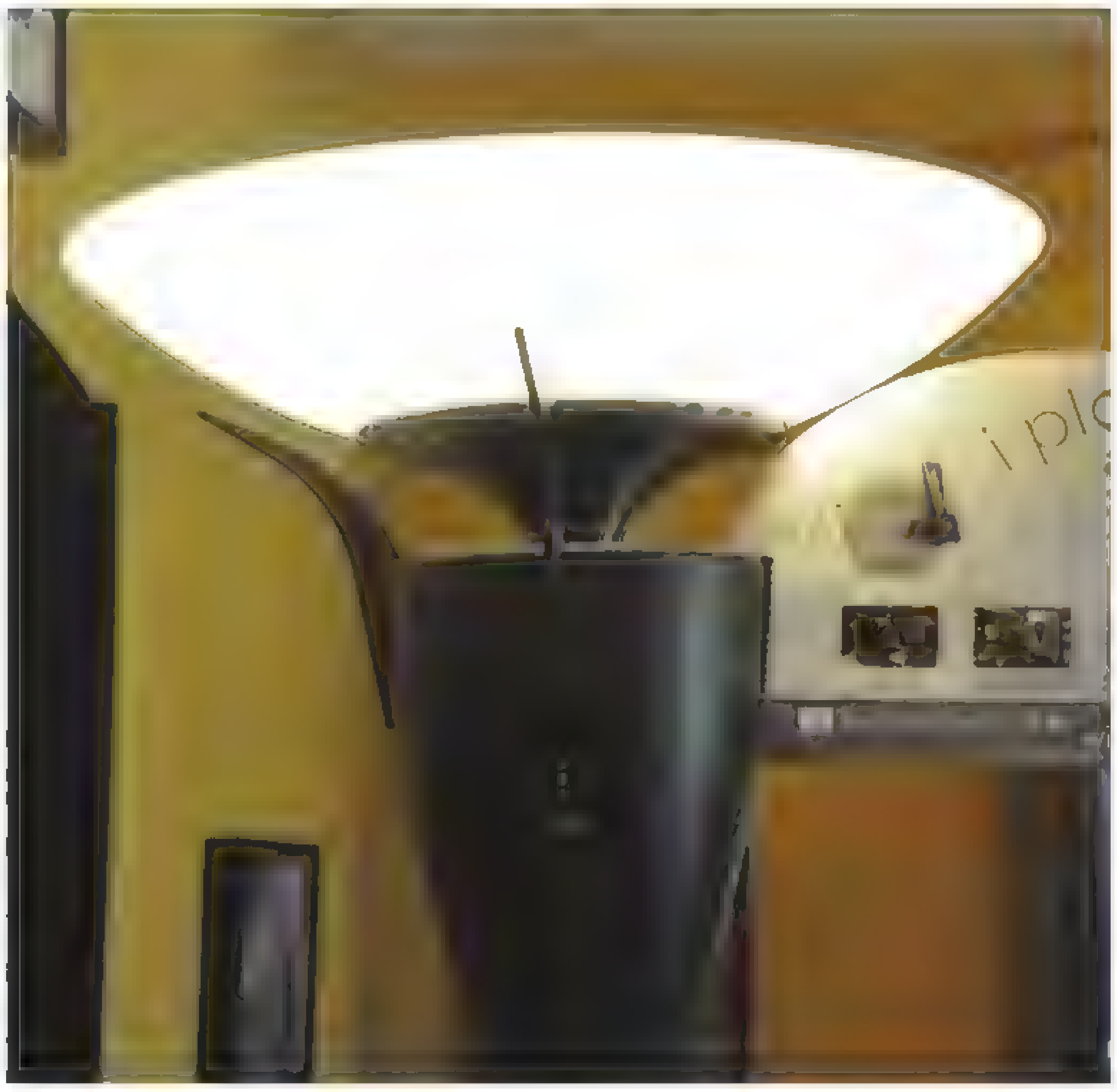
5 A table is lit by two bulbs above it. If you hold your hand above the table, you see different shadows.
What do you call:
a the dark shadow area in the middle?
b the two lighter shadow areas at either side?

6 What two kinds of light does the lamp in figure 48 produce?

7 When do you get the greatest contrasts between light and shadow:
a when it is a bit misty outdoors or when the sun is shining?
b when your desk is lit by a reading lamp or by a fluorescent tube?

8 State whether each of the following statements is true (T) or false (F).
a Warm lighting uses light that contains a relatively large amount of red, orange and yellow.
b Lamps that are used for mood lighting often give direct light.
c Indirect light is produced when the light from a lamp is reflected off a wall or ceiling.
d Mist scatters sunlight, producing a modified, diffuse light.
e The reflection of sunlight off freshly fallen snow is an example of mirror reflection.

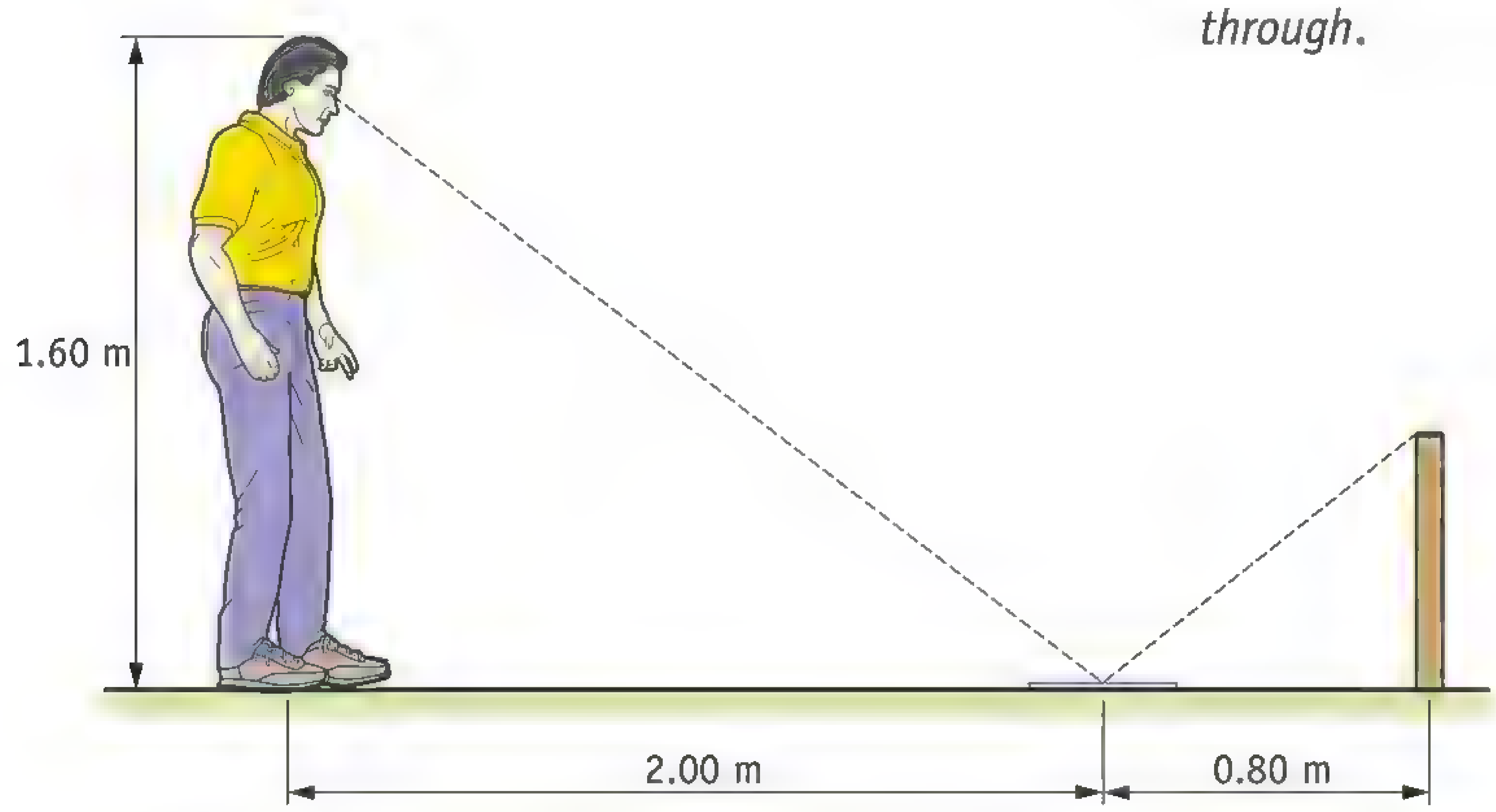
9 Tim says, "When sunlight hits a sheet of white paper, it is reflected in all directions."
Roy says: "When sunlight hits a mirror, it is reflected in one specific direction."
Who is right?
A They are both right.
B Only Tim is right.
C Only Roy is right.
D Neither of them is right.



▲ **figure 48**
a lamp that produces two kinds of light

10 Ten capital letters are shown below.
E H K M S T W X Y Z
Which of these letters look exactly the same if you look at them in a mirror?

11 Peter places a mirror (horizontally) between himself and a pole so that he can just see the tip of the pole in the mirror. See figure 49 for the rest of the data.
How high is the pole? Choose between:
A 64 cm
B 48 cm
C 96 cm
D 72 cm



▲ figure 49
Measuring height using a mirror.

12 A ray is reflected by a mirror. The angle between the incident and reflected rays is 80 degrees. What angle does the incident ray make with the mirror?

13 Even if you sit for hours in the Sun behind a window pane, you will not get a tan.
What would seem to be blocked by window glass?

14 Is IR radiation used in a
A remote control?
B solarium?
C sodium lamp?
D X-ray camera?

15 A blacksmith heats a horseshoe until it is red hot. What type (or types) of radiation is the horseshoe then emitting?
A only infrared
B infrared and visible light
C only ultraviolet
D ultraviolet and visible light

16 Select the correct options.
If you go skiing in sunny weather you need to rub on plenty of lotion to prevent sunburn. You need to do this because the snow reflects *infrared / ultraviolet* radiation. As well as that, the atmosphere above your head is *thicker / thinner* and more radiation will therefore *be absorbed / get through*.

17 You need worksheet 8-12 for this exercise.
An opaque plate and two spotlights have been put in front of a white screen. One spot is emitting red light and the other is emitting green.
Indicate on the worksheet what colours can be seen at the various places on the screen.

18 A theatre spotlight produces yellow light. Hannah wonders whether this is 'pure' light, like the light from a sodium lamp.
How can Hannah find out what colour or colours are present in the light from the spot?

19 Some kinds of rattlesnakes can 'see' infrared radiation (figure 50). They do this with special organs that are sensitive to infrared. These organs are in two small pits next to the eyes.

a A prey such as a mouse emits more infrared radiation that the things in its surroundings. Why?

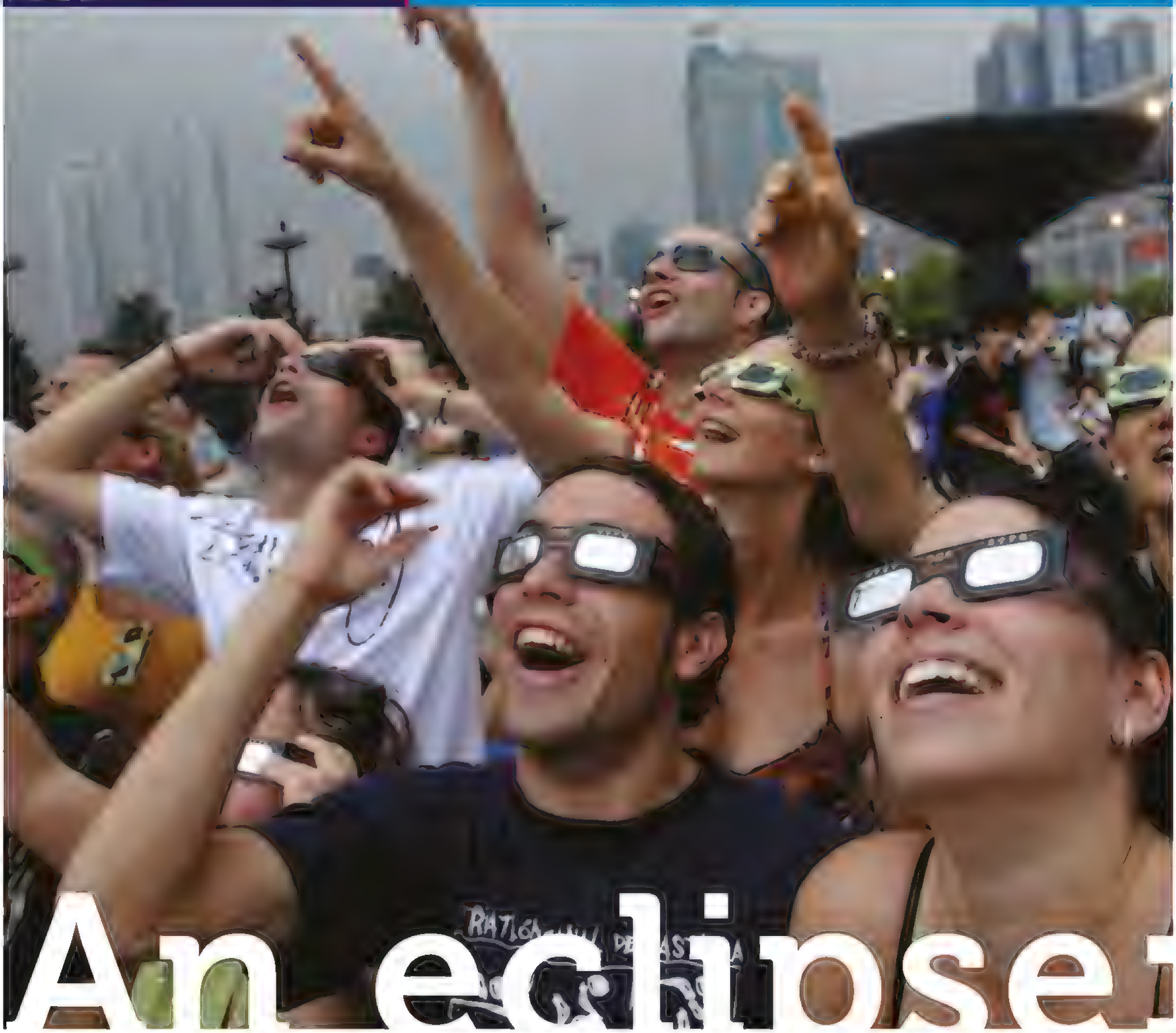
b When are the rattlesnake's 'infrared eyes' more useful: during the day or at night? Why?

▲ figure 50
A rattlesnake also uses infrared to see by.

***20** You need worksheet 8-13 for this exercise.
When a dentist examines your teeth he points a bright lamp at your mouth. There is then plenty of light on the front of your teeth, but not the back. The dentist therefore uses a small plane mirror to illuminate the back of your teeth. The worksheet shows how the light from the lamp falls on the mirror.

a Draw in the beam of light that is reflected by the mirror.

b Colour in the part of the tooth that is illuminated via the mirror.



An eclipse: a fascinating phenomenon

People who want to be there whenever there is a solar eclipse are called eclipse hunters. They travel all over the world just for that magic moment when the Sun disappears and the corona appears. "It's so impressive that you can't really explain it," said one of them. "You've just got to experience it." Many people apparently share that feeling. A total solar eclipse attracts thousands of interested people, every time.

Chasing eclipses is a modern phenomenon, something that has been made possible by affordable airline connections. You used only to see a solar eclipse about once in your entire life – and nobody had any problem with that. People were not happy to see the Sun – the source of light and life – suddenly seeming to be extinguished.

The ancient Greek poet Archilochus described the panic that broke out during one solar eclipse long ago. Writing after the eclipse of 6 April, 647 BC, he said: "Zeus, the father of the Olympian gods, changed broad daylight into night-time and concealed the light of the radiant Sun. A fearful dread came upon all the people."

Fortunately we now have a better understanding of what causes a solar eclipse. The phenomenon is now good for little more than a light-hearted news item, for example about an emotional eclipse chaser who is almost at a loss for words afterwards: "You're shaking and you can hardly say a word. Goosebumps. Tears. In one word: awesome!"

Not everybody responds so emotionally of course. Even so, there are very few people left completely unaffected by a total eclipse of the Sun, and that is more than enough reason to look at some of the facts behind this fascinating natural phenomenon. Five questions and answers.

"You're shaking and you can hardly say a word. Goosebumps. Tears. In one word: awesome!"

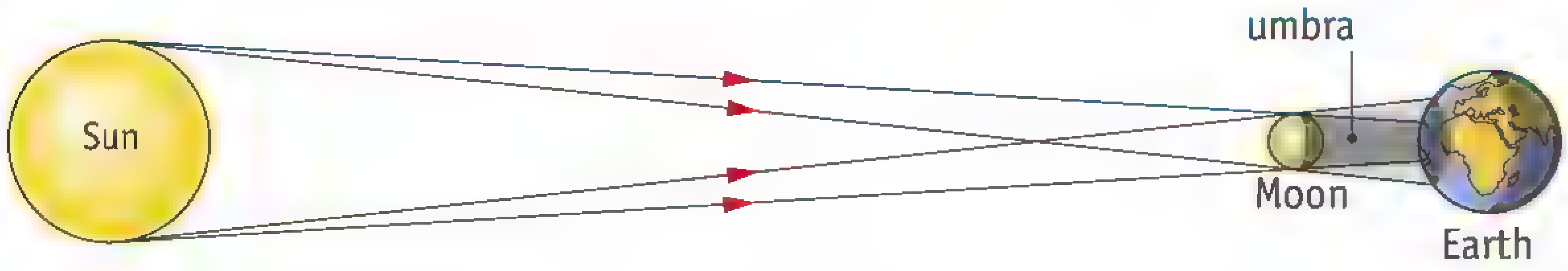
1 What causes a solar eclipse?

A solar eclipse occurs when the Moon (as seen from the Earth) moves in front of the Sun. It starts with the Moon taking a bite out of the disc of the sun. The first bite slowly increases to become a larger chunk. Finally, the Moon is right in front of the sun. The eclipse is then total. It then becomes peculiarly dark all around you and you can see the stars in the sky.

If you look towards the Sun during a total eclipse, you can see the corona: the extremely hot 'atmosphere' of the Sun, which extends a long way into space. The weak light from the corona is normally impossible to see in the much brighter sunlight. During a total eclipse, however, you can observe the corona as a luminous halo around the Sun. Sometimes it is also possible to see solar flares protruding from the perimeter of the dark disc of the moon.

2 Why is a solar eclipse only ever visible along a narrow path of land?

In a solar eclipse, the Moon's shadow is falling on the Earth. You



have an umbra and a much larger penumbra around it. The Sun is only fully obscured from view if you are in the umbra, and that area is small. Under the most favourable circumstances it is about 250 kilometres in diameter.

The shadow area moves very rapidly across the surface of the Earth. This is because the Earth is rotating about its own axis and the Moon is orbiting the Earth. The rapid progression of the shadow area means that new people keep seeing the eclipse.

3 Why isn't there a solar eclipse every month?

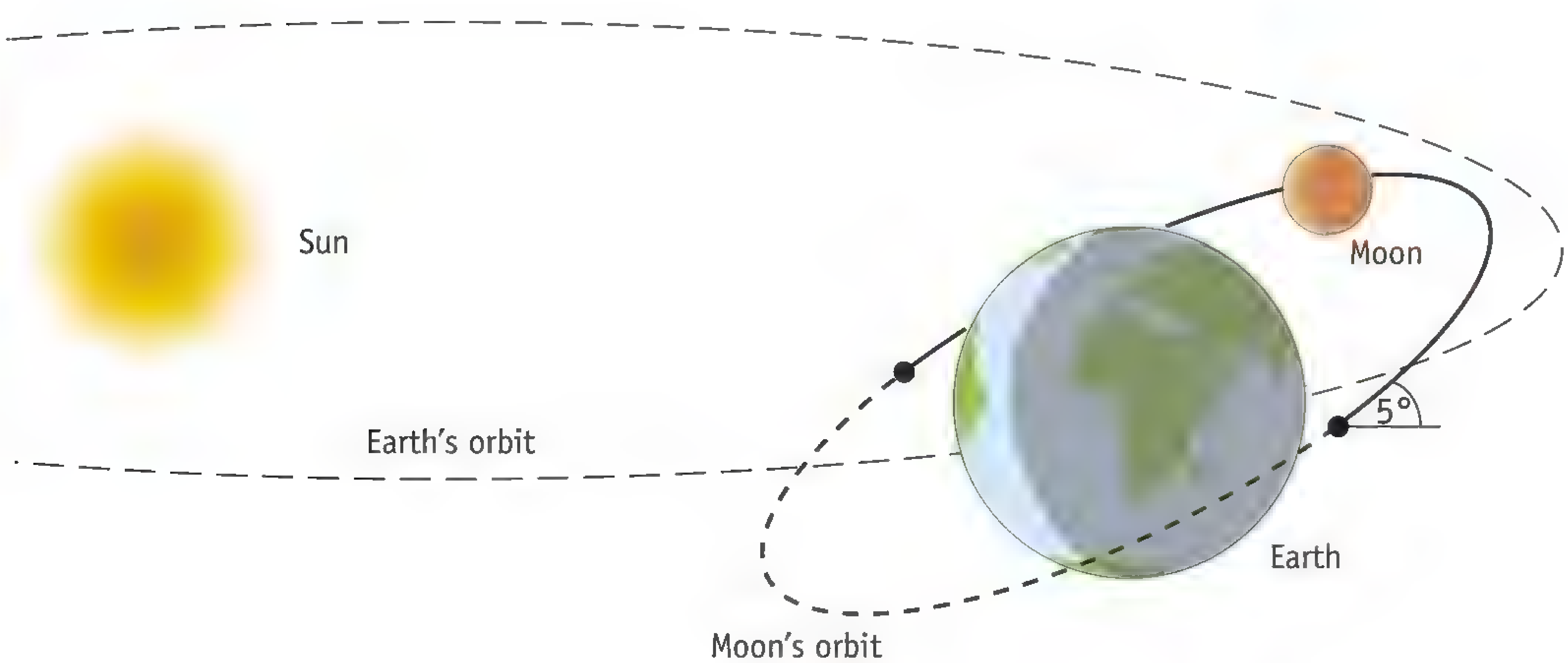
This is because the orbit of the Moon (around the Earth) is at an angle to the orbit of the Earth (around the sun). As you can see in the drawing below, the Moon's orbit is tilted at an angle of about 5° to the plane of the Earth's orbit. This means that the moon spends half its time above the plane of the Earth's orbit and the other half of the time below it.
Every month there is a short period when the Moon is invisible, during the new moon. The Moon is then between the Earth and the sun. That does not generally produce an eclipse, because the Moon is just above or just below the plane of the Earth's orbit. The umbra then passes above the Earth or below it. The Moon's shadow can only reach the Earth if the moon is crossing the Earth's orbit at that moment. This means that solar eclipses are relatively rare.

4 Why are there various different sorts of solar eclipses?

There are total, partial, annular and hybrid solar eclipses. In a total solar eclipse, the Moon completely obscures the Sun. In an annular eclipse, a thin outer ring of the sun's disc is still visible around the Moon. In a hybrid eclipse, an annular eclipse progresses to a total eclipse, and often then ends as an annular eclipse again.
These differences can arise because the Sun and the Moon are not always exactly the same size, as viewed from the Earth. For example, the distance between the Moon and the Earth varies from 363,000 kilometres to 406,000 kilometres. At its closest point, the Moon seems about 12% bigger than at its furthest. Such differences are smaller for the Sun, but they are still noticeable. This means that the Moon is able to obscure the sun entirely on some occasions, but not others.

5 How can you look at a solar eclipse without damaging your eyes?

The mix of visible, infrared and ultraviolet radiation given off by the Sun can easily damage your eyes. It is only safe to look towards the Sun during a total solar eclipse.



At all other times you must use eye protection.
Don't let anyone tell you that you can watch an eclipse wearing sunglasses or looking through a CD. Buy proper eclipse glasses (or borrow some welding goggles) and put them on before you turn to look at the Sun. These types of glasses or goggles absorb infrared and ultraviolet as well as weakening bright light: exactly what you need to make sure your eyes are all right for watching the next solar eclipse.

date	type	total eclipse duration	locations
29 April 2014	annular	-	Southern India, Australia, Antarctica
23 October 2014	partial	-	Pacific Ocean, North America
20 March 2015	total	2 min 47 s	Iceland, Europe, North Africa, Northern Asia
13 September 2015	partial	-	South Africa, India, Antarctica
9 March 2016	total	4 min 9 s	Eastern Asia, Australia, Pacific Ocean
1 September 2016	annular	3 min 6 s	South Africa, Indian Ocean
26 February 2017	annular	0 min 44 s	South America, Atlantic Ocean, Africa, Antarctica
21 August 2017	total	2 min 40 s	North America, South America

Exercises

1 In a partial solar eclipse, there is nowhere on the Earth's surface where the Sun is fully obscured. You see that the Moon takes a large bite out of the solar disc, but that bit never progresses to become a total or annular eclipse. Explain how a partial eclipse can occur. Use the words 'umbra' and 'penumbra'.

***2** Search for information on the Internet about the next total solar eclipse.
- **a** How long will the trail be that the umbra leaves across the surface of the Earth?
- **b** How fast does the shadow area move across the surface of the Earth?
- **c** How wide is the trail along which the total solar eclipse will be visible?

3 You need worksheet 8-14 for this exercise.
The worksheet has a drawing of a *lunar* eclipse (not to scale).
- **a** Fill in the names at the correct places: Sun, Moon and Earth.
- **b** Draw in the umbra and penumbra of the Earth.
- **c** Is it possible for you to see a complete lunar eclipse from one place on the Earth's surface but only a partial one from another place? Explain.
- **d** Suppose that there were people on the Moon at this time.
What would they observe during a lunar eclipse?

 © Uitgeverij Malmberg

Skills

Doing research

Natural sciences is a subject that teaches you how to do research. You work with practical equipment, make measurements, draw graphs and do calculations. This part of the book is about the skills that you need in order to do this.

1 Doing research

Natural sciences is a subject that teaches you how to carry out research yourself. When you are doing research, you set about it step by step.

- **Step 1: Think of a study question**
The question you are investigating is usually already stated in the book – in which case this step won't take long. Sometimes the book lets you think up a study question of your own. Don't be content with your suggestion too quickly, and also be ready with an idea of how you could answer your question.

- **Step 2: Make a working plan**
In your working plan you should write down:
– what materials and equipment you will need;
– what experimental setup you are going to construct (make a drawing);
– what variables you are going to measure;
– which formulae you are going to use (if applicable).
Figure 1 gives an example of a working plan.

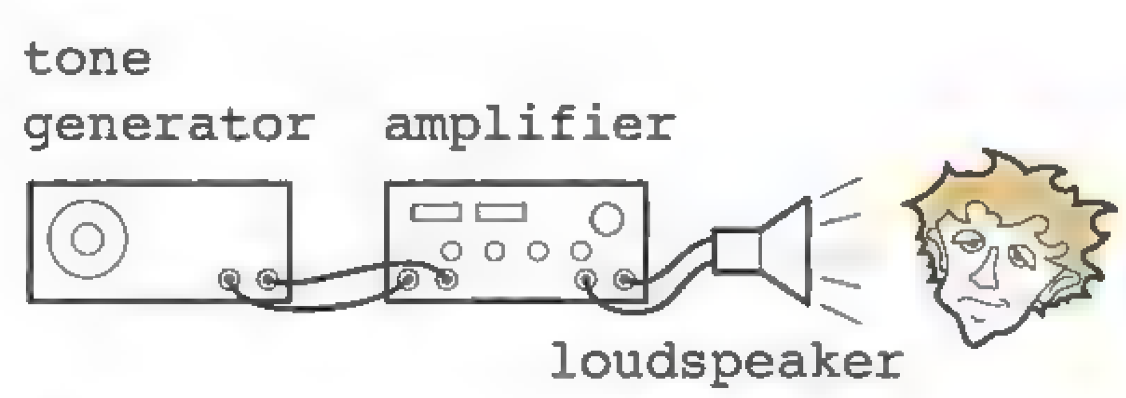
Working plan by: Eileen and Jamila

Study question: What is the highest tone we are able to hear?

1 Materials and equipment

* Tone generator
* Amplifier
* High-frequency loudspeaker

2 Setup



3 Measurements

Jamila uses the tone generator to produce increasingly high-pitched sounds. Eileen says "stop" when she can no longer hear the sound. Jamila then looks at the tone generator to see how high the frequency was. We do this a number of times to see if we consistently get the same value. Then we do the test again, but this time with Jamila listening and Eileen turning the knobs on the tone generator.

▶ figure 1
A working plan may look something like this.

- **Step 3: Doing the experiment and writing it up**
  You are now going to make the measurements and use them in the calculations.
  See also Skills 5 to 11.

- **Step 4: Drawing conclusions**
  If everything has gone as intended, you are now able to draw your conclusions. Try to give an answer to your study question. You should also think about what you could have improved your research.

- **Step 5: Writing a report**
  Finally, you make a report of your research. See Skills 14.

2 Working with variables and units

Experiments and study assignments often need you to make measurements. You use a measuring instrument to find a numerical value for a property, such as a length or a temperature.

▲ figure 2
The variable 'height' is measured in the units 'metres'.

Variables
A **variable** is a property that you can measure with a measuring instrument. Examples of variables are length, mass and temperature. You can measure these variables with a ruler (for the length), scales (for the mass) or a thermometer (for the temperature).

Units
Before you can measure a variable, a scale of sizes has to be agreed. This scaling is known as a unit. You measure your length in metres, your mass in kilograms and your body temperature in degrees Celsius.

There is an internationally recognised set of units, known as **SI units**, for every variable, such as the metre for length, the second for time and the kelvin for temperature. Other units are also used in everyday life. People use them because they find these units handier, or simply because it is what they're used to.

Noting down measurement results

- Before making the measurements, determine what units your measuring instrument gives the results in. That is often immediately clear, but sometimes you do have to look carefully first.
- Always make a note of a measurement result straight after taking it.
- If you are only making a single measurement, note the measurement result down in this form: [variable] = [value] [units].
- For example, mass = 237 grams or m = 237 g.

If you are making a series of measurements, you should then record your measurement results in a table. Above each column of numbers, you should write:
– what variable you have measured;
– which units you have used (in brackets).

Table 1 gives a summary of the variables and units that you will come across in this book. The third and fourth columns give the SI units. Other widely used units are listed in the last two columns.

Sometimes you have to convert a value from one set of units to another (for instance from km/h to m/s). See Skills 4 for this.

▼ **table 1** variables and units

variable	abbreviation	SI unit	abbreviation	other units	abbreviation
density	ρ	kilograms per cubic metre	kg/m^3	grams per cubic centimetre	g/cm^3
frequency	f	hertz	Hz	-	-
length, distance	l	metre	m	-	-
pressure	p	pascal	Pa	bar	-
mass	m	kilogram	kg	-	-
speed	v	metres per second	m/s	kilometres per hour	km/h
voltage	U	volt	V	-	-
current strength	I	ampere	A	-	-
temperature	T	kelvin	K	degrees Celsius	°C
time	t	second	s	minute, hour	min, h
power	P	watt	W	-	-
volume	V	cubic metre	m^3	litre	L

3 Working with prefixes

A unit may sometimes be awkwardly large or indeed awkwardly small. A method has therefore been developed for making units that are the 'right size'.

The **prefixes** in table 2 can in principle be used for any unit. You can for example make derived units that are 10, 100 or 1000 times larger or smaller than the original unit. This lets you adjust the size of the unit to suit the situation: kilograms for the mass of your body, but milligrams for the amounts of active ingredient in a tablet.

In practice, some combinations are widely used and others very rarely or never. The decibel (dB) is a popular unit, for example, but you will never come across a decivolt (dV) or deciwatt (dW).

▶ figure 3
a painkiller with 500 mg of the active ingredient per tablet

Choosing a unit

- When doing your experiments, you should look to see what units are stated on the measuring instrument. It is generally simplest to use those units.
- Choose a smaller unit if you would otherwise end up using very small numbers (< 0.1). Record the result of a volume measurement as 25 mL, for example, rather than 0.025 L.
- Use a larger unit if you would otherwise end up with very large numbers (> 1000). Record the result of a calculation as 340 km, for example, rather than 340,000 m.

Sometimes you have to convert a value from one set of units to another (for instance from mA to A). See Skills 4 for this.

▼ **table 2** prefixes and their meanings

prefix	abbreviation	meaning	example
kilo	k	1000	1 kg = 1000 g
hecto	h	100	1 hPa = 100 Pa
deca	da	10	1 dam = 10 m
deci	d	1/10 = 0.1	1 dL = 0.1 L
centi	c	1/100 = 0.01	1 cm = 0.01 m
milli	m	1/1000 = 0.001	1 mA = 0.001 A

4 Converting units

You often have to convert from one set of units to another. For instance you might do this if you have calculated the speed in m/s but someone asks you what that is in km/h.
When you need to convert units, you do it as follows:

- **Step 1: Write down an equation with one unit on the left and the other on the right.**
- **Step 2: Determine which number you need to multiply (→) or divide (←).**
- **Step 3: Do the appropriate multiplication or division and write down the result.**

▲ figure 4
As you can see from this measuring jug, 1 L is the same as 1000 mL.

Worked example 1
A measuring cylinder contains 0.125 L water. How many millilitres is that?

Step 1: Note (or look up) the fact that 1 L is the same as 1000 mL – see figure 4.
Step 2: You a going from litres to millilitres, so you have to multiply by 1000.
Step 3: Work it out: the volume of the water is 0.125 x 1000 = 125 mL.

Worked example 2
An ammeter shows 82 mA. How many amps is that?

Step 1: Note (or look up) the fact that 1 A is the same as 1000 mA.
Step 2: You are going from mA to A, so you have to divide by 1000.
Step 3: Work it out: the current is 82 : 1000 = 0.082 A

Worked example 3
A cyclist's speed is 5.2 m/s. What is that in km/h?

Step 1: Note (or look up) the fact that 10 m/s is the same as 36 km/h.
Step 2: You are going from m/s to km/h, so you are multiplying by 3.6.
Step 3: Work it out: the speed is = 5.2 x 3.6 ≈ 19 km/h.

5 Reading measuring instruments

When you make a measurement, you read off a measured value – a number – from a measuring instrument. This is easier for some measuring instruments than for others.

A **digital measuring instrument** such as a digital stopwatch or a digital clinical thermometer is electronic. The measured value is shown in numeric form on a screen. These types of meters make it very easy for you: all you have to do is note down the numbers.

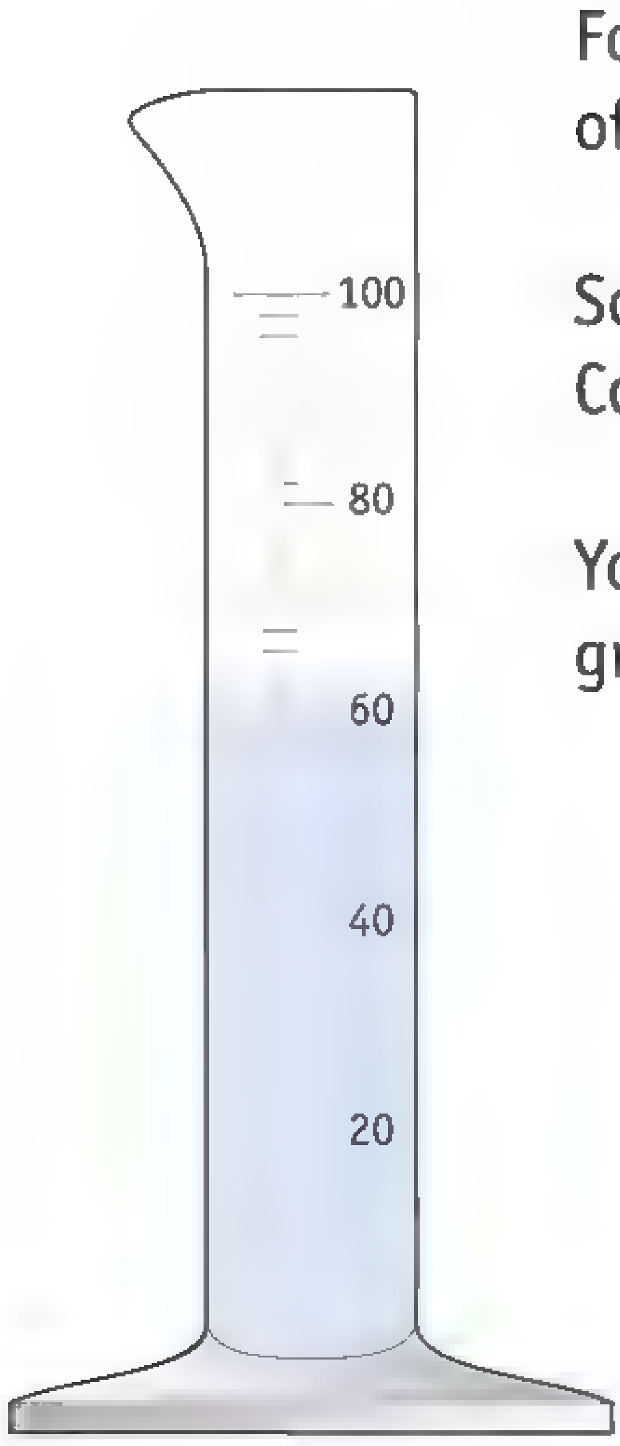
An **analogue measuring instrument** such as a measuring cylinder or an analogue voltmeter uses a graduated scale. You read off a measuring cylinder by looking to see which mark the liquid level is at. For an analogue voltmeter, you look to see which mark the needle is pointing at.

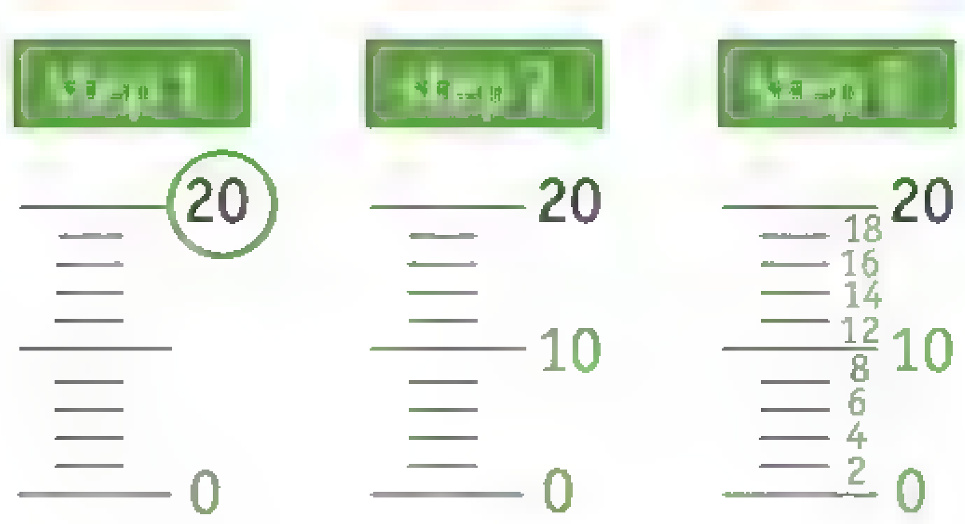
For measuring instruments such as these, you cannot read off the measurement value immediately. First you have to know how much each mark represents. You can work that out as follows:

- **Step 1: Go from the zero to the first numbered mark.**
  In the measuring cylinder in figure 5, this is the line with a 20 next to it.
- **Step 2: Go to the line half way between the zero and the first number.**
  Work out what value belongs with this mark. For the measuring cylinder, that would be 10.
- **Step 3: Now determine the value of each individual mark on the graduated scale.**
  Count from 0 up to the first number to check that you've got it right. For the measuring cylinder, it will work out correctly if you count in steps of 2 mL.

So each marker on the measuring cylinder represents 2 mL.
Confirm for yourself that this measuring cylinder contains 62 mL of water.

You can use the same method for other measuring instruments with graduated scales.





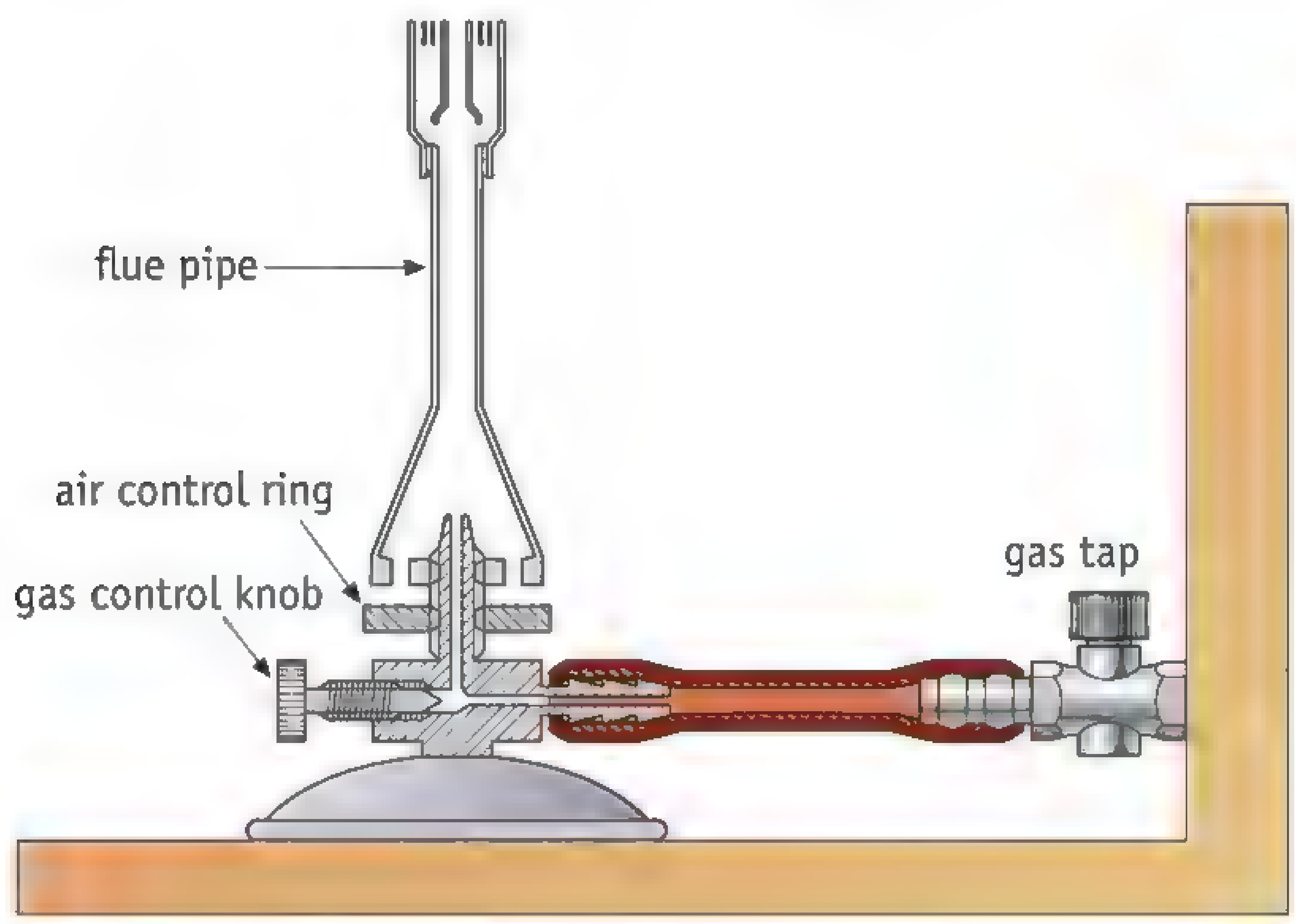
▶ figure 5
How to read a measuring cylinder.

6 Working with a Bunsen burner

For physics and chemistry you will sometimes use a Bunsen burner. The instructions below tell you how to use it.

Safety
- Stick to the safety rules that you have discussed with your teacher.

Before starting
- Check that the gas control knob and air control ring of the burner are closed (figure 6). If not, close them.



▶ figure 6
the parts of a Bunsen burner

Lighting
- Connect your burner to the gas tap on your bench.
- Open the gas tap.
- Hold a burning match above the burner.
- Open the gas control knob.
- The burner will now burn with a clearly visible, yellow flame.

Heating
- Open the air control ring.
- The burner now burns with a poorly visible, blue flame. This blue flame is much hotter than the yellow flame. You generally use a quietly hissing, blue flame to heat things (never a yellow flame).

Interrupting an experiment
- Do not leave the Bunsen burner unattended when the flame is blue.
- Always close the air control ring first.
- The burner then burns with a clearly visible, yellow flame.

Turning it off
- Close the air control ring.
- Close the gas tap on your bench.
- Close the gas control knob.

 © Uitgeverij Malmberg

7 Working with a voltmeter

Experiments with electricity often use a voltmeter. You must connect this kind of meter correctly.

Connecting

- To measure the voltage across a bulb, you connect the voltmeter in parallel with the bulb. See figure 7.
- Connect the positive terminal of the battery or power supply to the positive connection on the voltmeter. The needle will then move in the right direction. If the needle moves to the left you should connect the two wires to the meter the other way around.

Measurement ranges

- Many voltmeters have various different measurement ranges. For instance, the meter in figure 7 has three measurement ranges: 0-5 volts, 0-15 volts and 0-30 volts. If you use the 0 to 5 V measurement range, you can measure voltages up to a maximum of 5 V.
- Do a test measurement first using the largest measurement range. This helps make sure that the meter will not get damaged. You can then see clearly whether or not you should use a smaller measurement range.
- You should then make the measurements using the smallest possible measurement range. The needle will then move further and you can read what it is showing more accurately.

Reading

- Always look at the meter as directly from the front as possible and do your best to read the value off accurately.

▶ figure 7
How to connect a voltmeter.

 © Uitgeverij Malmberg

8 Working with an ammeter

Experiments with electricity often use an ammeter. You must connect this kind of meter correctly.

Connecting

- To measure the current through a bulb, you connect the ammeter in series with the bulb. The current flowing through the bulb then also has to flow through the meter.
- Connect the positive terminal of the battery or power supply to the positive connection on the ammeter. The needle will then move in the right direction. If it moves to the left you should connect the two wires to the meter the other way around.

Measurement ranges

- The ammeter will usually let you choose from a number of different measurement ranges. The meter in figure 8 has three: 0-5 mA, 0-500 mA and 0-5 A. If you use the 0 to 500 mA measurement range, you can measure currents of a maximum of 500 mA.
- Do a test measurement first using the largest measurement range. This helps make sure that the meter will not get damaged. You can then see clearly whether or not you can use a smaller measurement range.
- Then do the measurement with a smaller measurement range if possible. If you can see that the current is about 30 to 40 mA, for example, you could switch down to the 0-50 mA range. The needle will then move a long way and you can read accurately what it is showing.

Reading

- Always look at the meter as directly from the front as possible and do your best to read the value off accurately.

▶ figure 8
How to connect an ammeter.

Nova © Uitgeverij Malmberg

9 Working with a multimeter

In experiments with electricity, you can use a multimeter instead of a voltmeter or an ammeter. There is a knob on the meter that makes it easy to choose the variable being measured and the desired measurement range (figure 9).

Measuring a voltage

- Turn the knob to the area marked 'DCV' or 'V=' and select the largest measurement range.
- Connect the multimeter like a voltmeter: in parallel with the bulb.
- Make a test measurement. Repeat this if necessary using a smaller measurement range.
- Finally make the 'real' measurement using the smallest possible measurement range.

Measuring a current

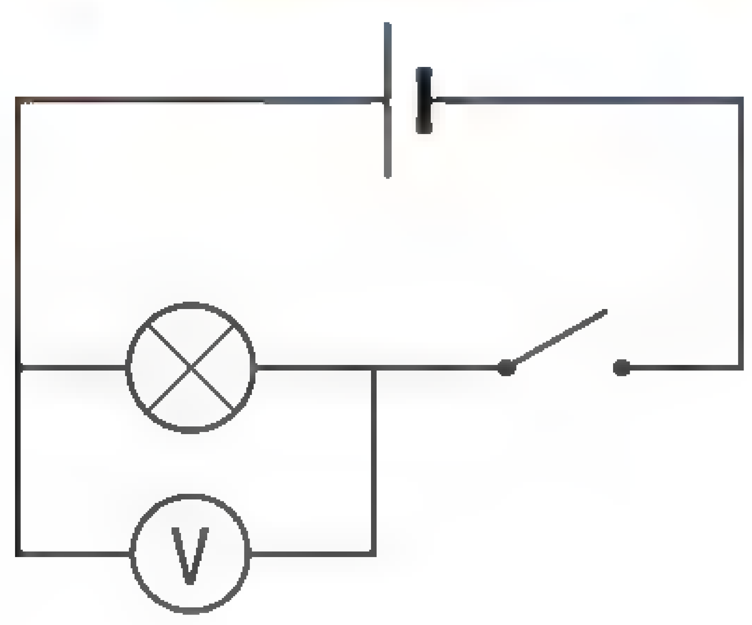
- Turn the knob to the area marked 'DCA' or 'A=' and select the largest measurement range.
- Connect the multimeter like an ammeter: in series with the bulb.
- Make a test measurement. Repeat this if necessary using a smaller measurement range.
- Finally make the 'real' measurement using the smallest possible measurement range.

▶ figure 9
a multimeter

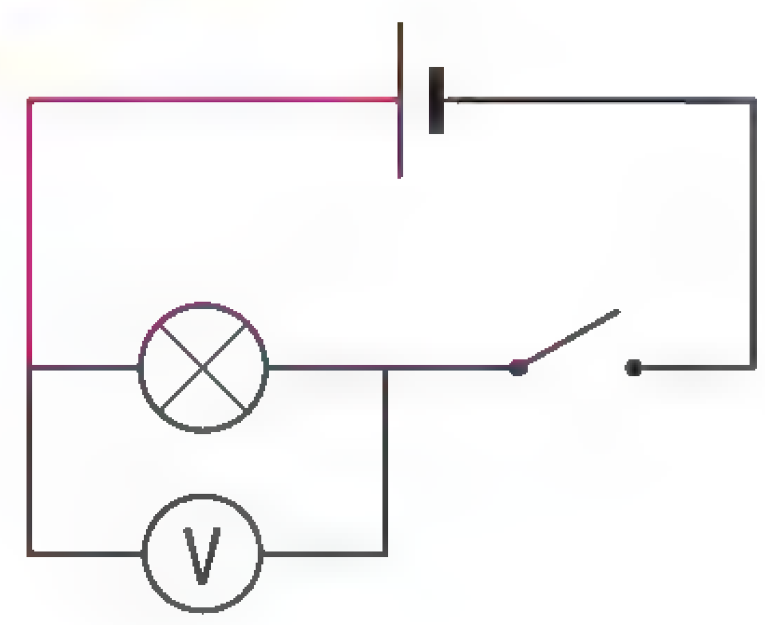
Nova © Uitgeverij Malmberg

10 Building circuits

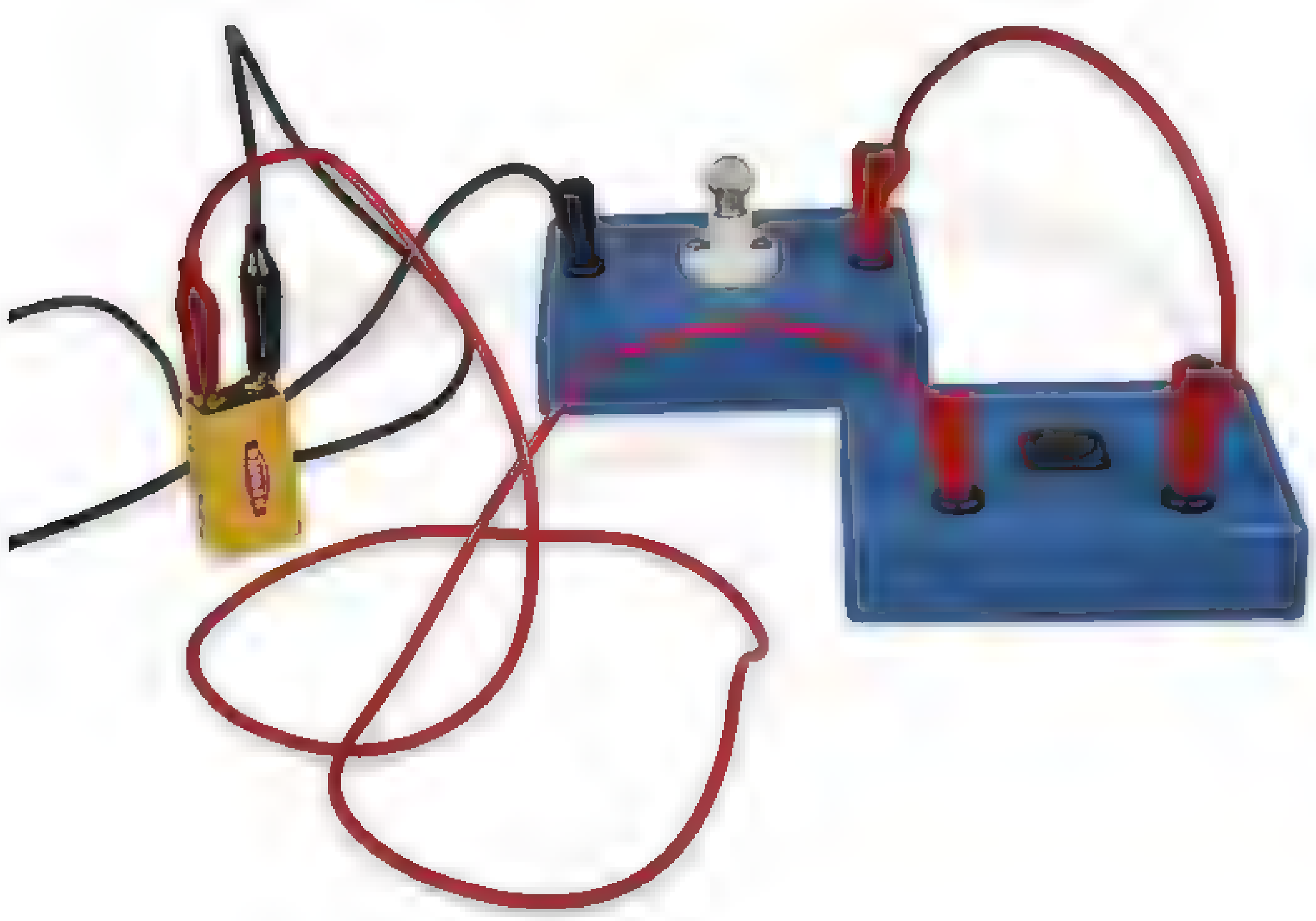
For some experiments, you use a circuit diagram to help put a circuit together. The best way to build a circuit is to do it step by step. Figure 10 shows you how.

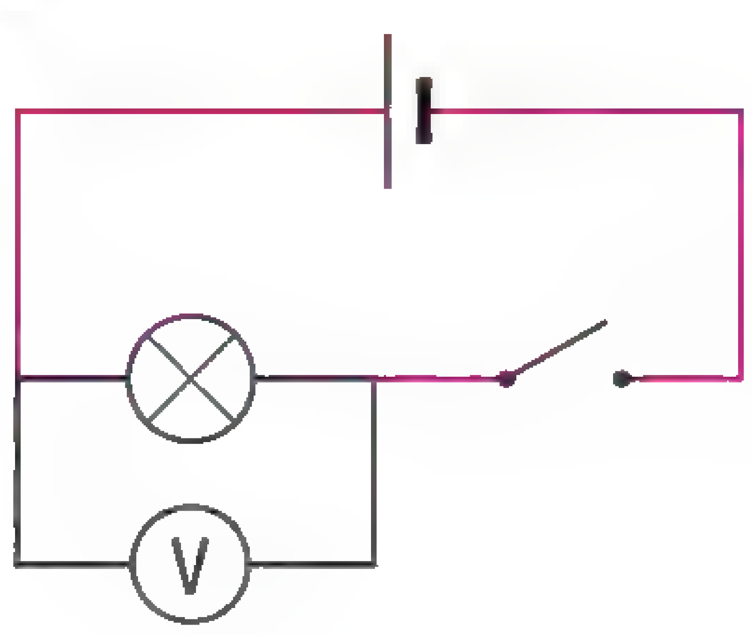


1 Collect the various components.

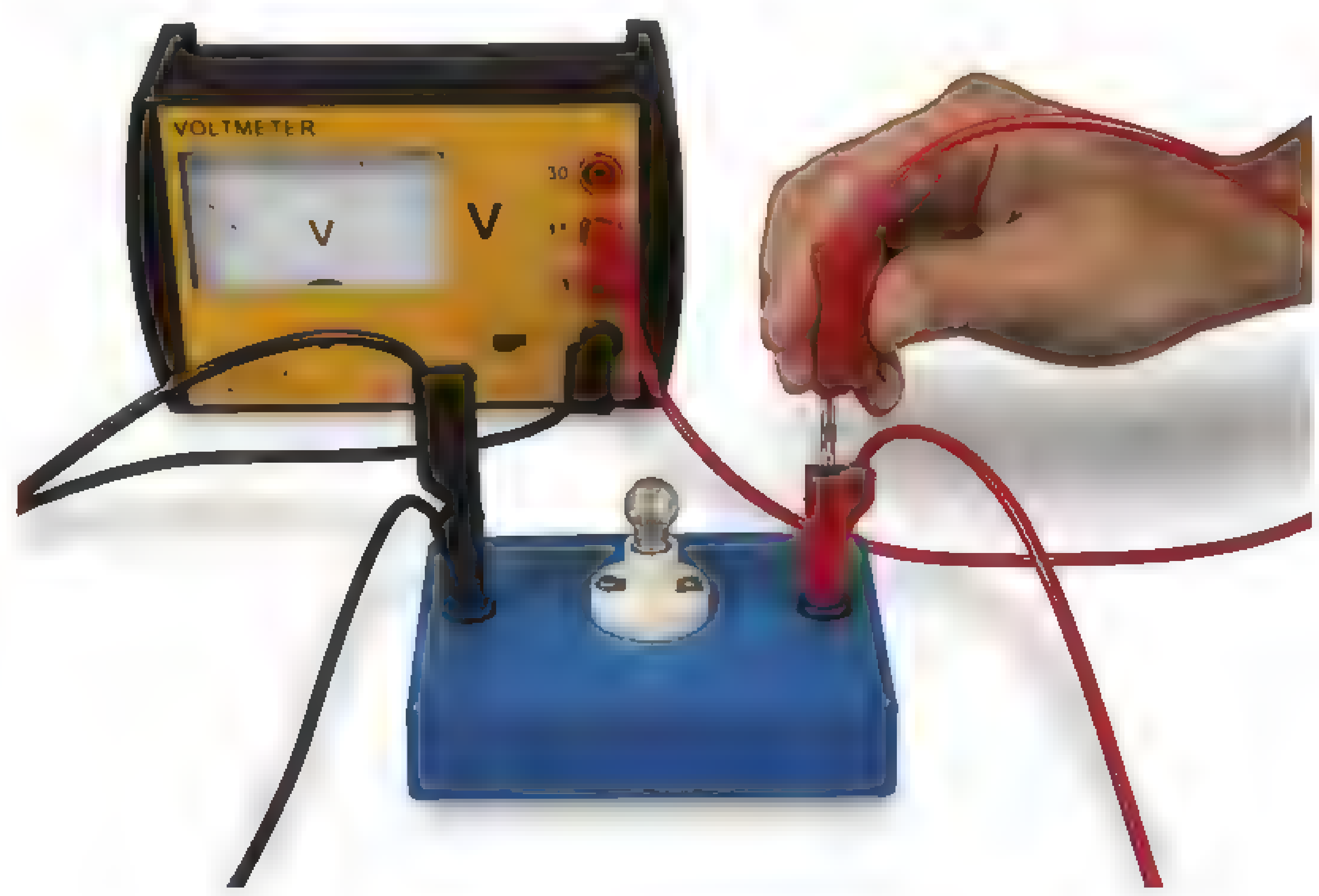


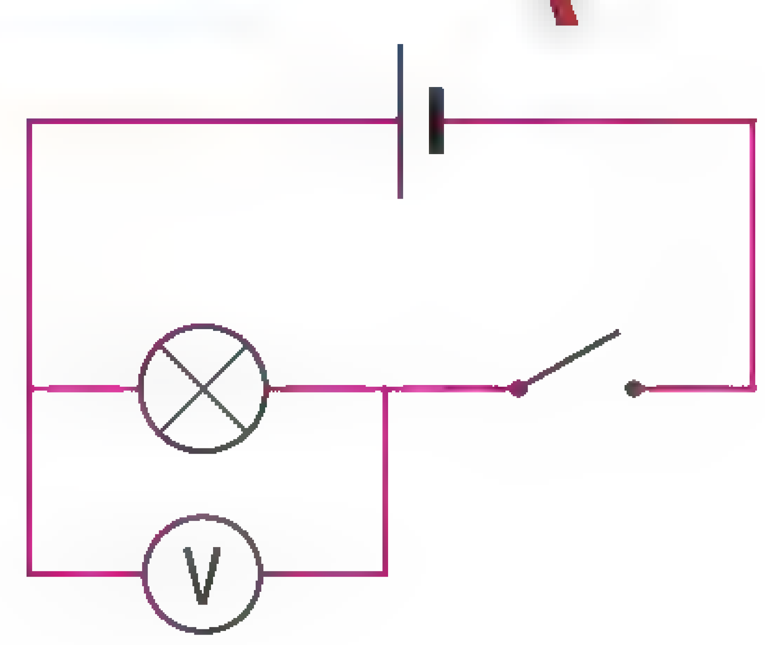
2 Start with a red wire on the plus side.





3 Connect the bulb and the switch, in series.





4 Connect the voltmeter in parallel with the bulb.

▲ figure 10
Building a circuit.

11 Working with an oscilloscope

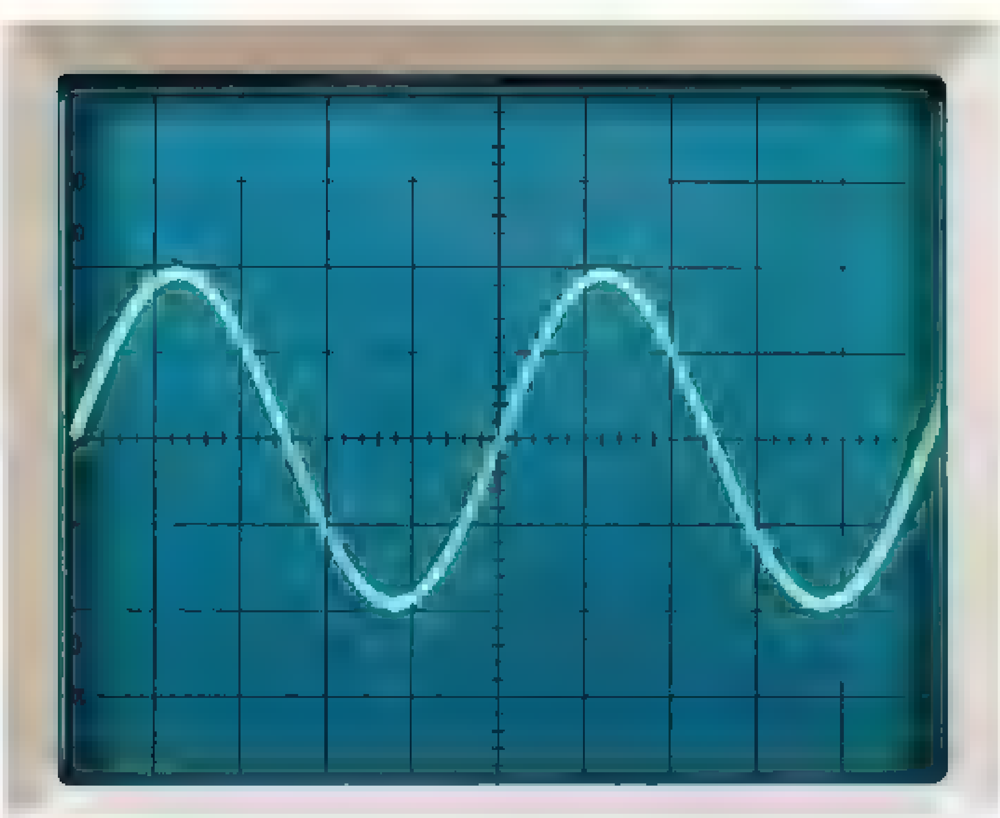
An oscilloscope lets you determine the frequency of a tone. To do that, you first have to connect a microphone to the input of the oscilloscope. The screen then shows a picture of the sound vibration.

▲ **figure 11**
The time base of an oscilloscope.

The time base
The oscilloscope screen is subdivided into squares. Time is presented along the horizontal axis. If a single square is 2 milliseconds wide, we say that the time base is set to 2 milliseconds per division (2 ms/div). There is a knob on the oscilloscope that you can turn to set the time base (figure 11).

Setting the time base

- Sometimes there will be too many vibrations on the screen at once. You should then set the time base to a smaller value.
- Sometimes all you can see is a small part of a single vibration. You should then set the time base to a larger value.
- The time base is set correctly if you can see just a few vibrations on the screen. You are then easily able to read off from the screen how much time is needed for a single vibration (figure 12).



▲ **figure 12**
An oscilloscope picture of a vibration.

Worked example
The time basis for the oscilloscope in figure 12 is set to 2 ms/div (2 milliseconds per division).
Calculate the frequency of the vibration shown.

You can see that one complete vibration takes up five squares.
$T = 5 \times 2 \text{ ms} = 10 \text{ ms} = 0.01\text{s}$

$$f = \frac{1}{T} = \frac{1}{0.01} = 100 \text{ Hz}$$

Nova © Uitgeverij Malmberg

12 Working with formulae

In science you will sometimes need to do calculations. You have to be able to show clearly how you got your answer.

You should therefore show the working for your calculations as follows:

- **Step 1: Write down all the data you are using.**
- **Step 2: Make a note of what you are being asked to find.**
- **Step 3: Note down the formula in an appropriate form.**

You write down the formula for the power P as:

$P = U \times I$ if you have to calculate the power P.

$U = \dfrac{P}{I}$ if you have to calculate the voltage U.

$I = \dfrac{P}{U}$ if you have to calculate the current I.

- **Step 4: Fill in the data.**
- **Step 5: Note down the answer, as a number followed by its units.**

Round off the answer if your answer would otherwise contain too many digits. A good rule of thumb is that your answer should have the same number of digits (or at most one more digit) than the data item with the fewest digits. You can show that you have rounded the answer off by using the ≈ symbol instead of =.

Worked example
A metal cylinder has a mass of 196 g and a volume of 22 cm^3.
Calculate the density of the material that the cylinder is made of. What substance might it be?

given $m = 196 g$
$V = 22\ cm^3$

required $\rho = ?$

working $\rho = \frac{m}{V} = \frac{196}{22} \approx 8.9\ g/cm^3$

The cylinder could very well be made of copper: see table 2 in section 4 of chapter 2.

13 Working with tables and graphs

Many of the study questions are about the relationship between two variables. Take the following study question, for example:
What is the relationship between the temperature of water in a glass beaker and the time for which the water is heated?

This question is about the relationship between time and temperature. To answer the question, you carry out a series of measurements. You heat the water with a Bunsen burner. At one minute intervals you read the water temperature from a thermometer. You then note down the measurement results in a table (see figure 13a). After completing the experiment, you show the measurement results in a graph.

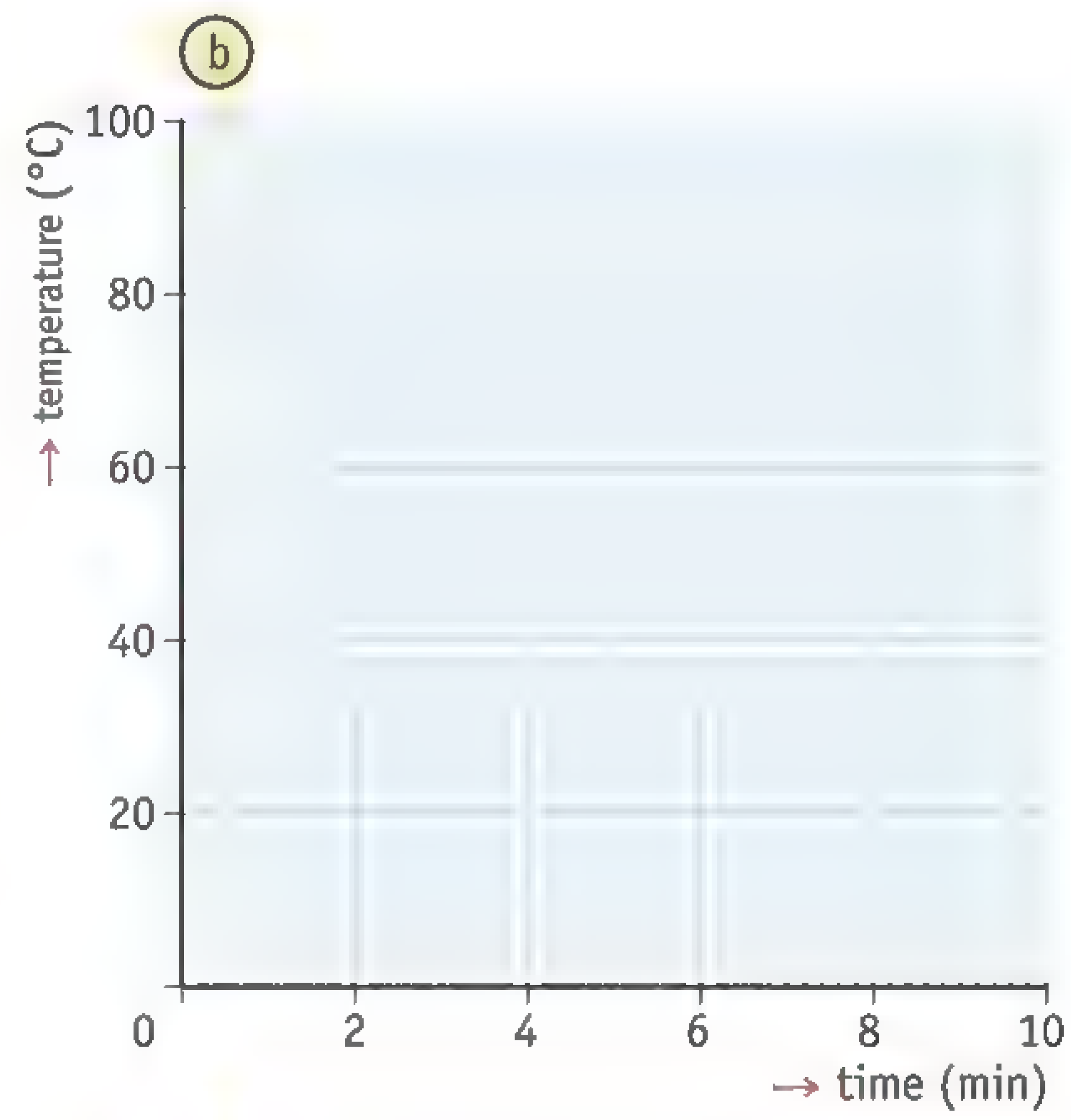
 © Uitgeverij Malmberg

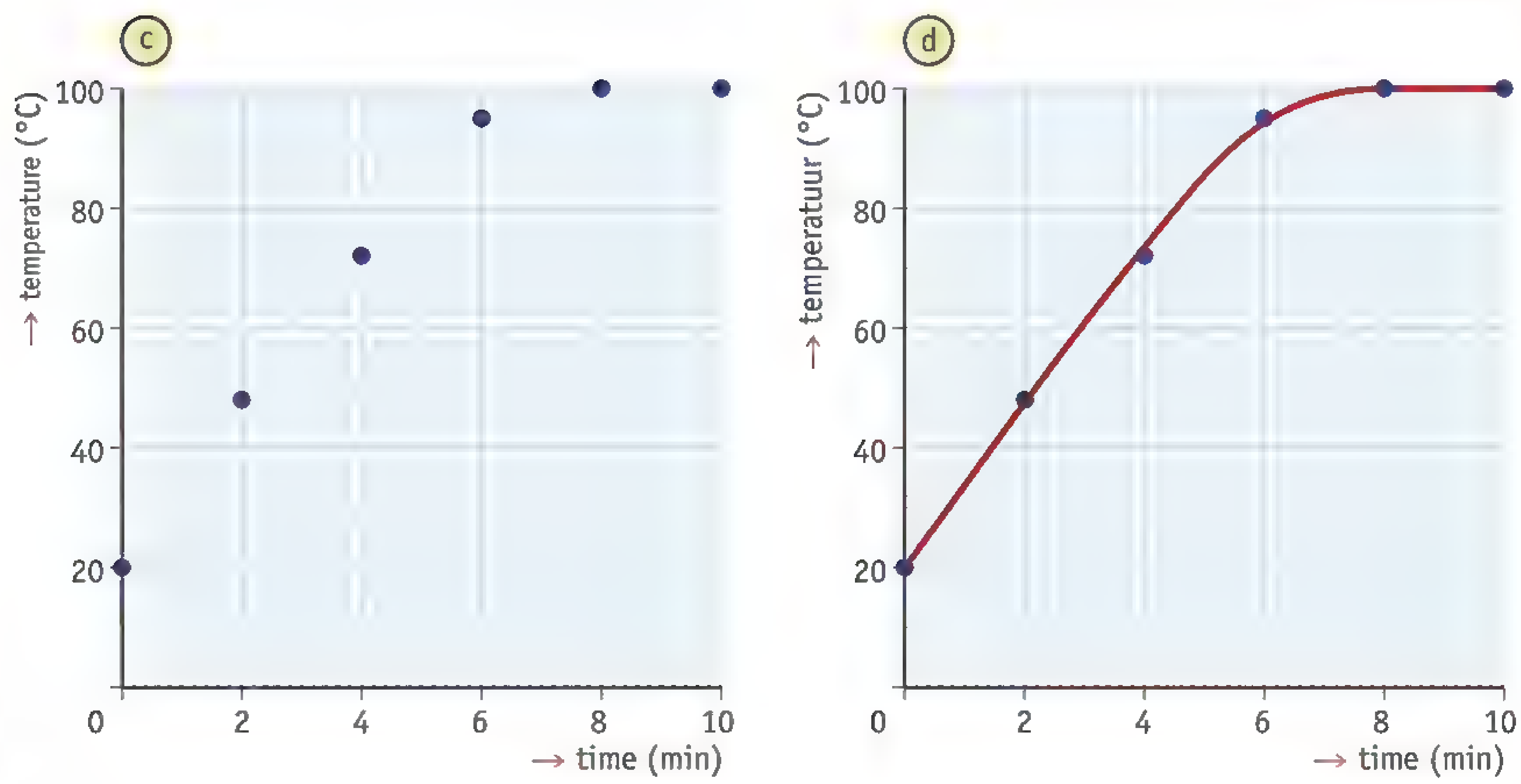
This is how you make the graph (see figures 13b, c and d):

- **Step 1: Draw a set of axes.**
- **Step 2: Label each axis with a variable and the corresponding units.**
  For example: → time (min) and → temperature (°C).
- **Step 3: Draw an appropriate scale along each of the axes.**
- **Step 4: Plot the measurements as points.**
- **Step 5: Draw a straight line or a smooth curve that fits the points as well as possible. You should not simply join the dots.**
  In other words, it does not matter if the straight line or curve does not go precisely through all the measurement points.

a

time (min)	temperature (°C)
0	20
2	48
4	72
6	95
8	100
10	100





▶ figure 13
from a table to a graph

14 Writing a report

Research has to be written up. In the report, you should explain what happened during the experiment. Somebody who was not actually there must be able to understand exactly what happened. Sometimes you also have to write a report of a practical experiment or a home assignment.

Lay your report out like this:

- Title page
  This is where you can give the title of the report, the names of the pupils in the group doing the experiment, the class, the name of your teacher and the date and year.

- Section 1: Study question
  This section is where you explain what question you wanted your study to answer.

- Section 2: Working plan
  This contains:
  – a list of the things you used;
  – a drawing of the experimental setup you made;
  – a brief description of what you did.

- Section 3: Experimental results
  This is where you can state what you observed or measured. This can be in textual form or as tables, graphs, photographs and so forth.

- Section 4: Conclusions
  The answer to the study question can be stated here.

A report should look good. It is not only about the information that your report contains: you must also present that content clearly and neatly.

Index

Acknowledgements

Authors:
P. van Hoeflaken
R. Tromp

Editors:
K. Gibbs
R. Tromp

With help from:
Th. Smits

Illustrations:
Technisch tekenburo BB, Tiel
Yde Bouma, Leusden
Erik Eshuis, Groningen
Anke Nobel, Lelystad
Flohr Vormgeving, De Meern

Cover photo:
Shutterstock

Chapter openers:
Shutterstock, Hollandse Hoogte, Corbis Images

Image acquisition:
Fundamentaal communicatie|educatie, Culemborg

Design:
Uitgeverij Malmberg, Den Bosch

Translation:
Mike Wilkinson/Tessera Translations BV, Wageningen

Layout:
Asterisk*, Amsterdam

ISBN 978 90 345 8354 3
Vierde editie, zesde oplage

MALMBERG

Photos:
AGU BV, Alkmaar: p. 281
Audion Elektro BV, Weesp: p. 98
Barco n.v., Kortrijk, Belgium: p. 256
Canstockphoto.nl, AnnieAnnie: p. 31
Cindy Heijkoop, Papendrecht: p. 49, 50, 65, 268
Corbis Images, Amsterdam: p. 62, 96, 99, 192, 233
Dave Taylor: p. 293
Eurofysica, Rosmalen: p. 46
Eurol BV, Nijverdal: p. 78
Fotosearch: p. 96
Fundamental Photographs, Richard Megna, 58, 211
Getty Images, : p. 11, 33, 48, 70, 90, 175, 178, 216 259, 274, 276, 285, 298
Gijs Versteegh: p. 170
Hollandse Hoogte: p. 11, 14, 50, 91, 97, 108, 125, 142, 155, 168, 169, 184, 217, 236, 240, 241, 242, 262, 296, 303
http://cab.inta-csic.es/rems/marsweather.html: p. 130
Jakob Breimer, Zeeland: p. 22, 24, 61, 73, 120, 130, 137, 140, 143, 149, 153, 164, 247, 253, 270, 300, 312
Jorrit Lousberg/Nuon Solar Team: p. 171
Larry Reed and Shadowlight Productions: p. 292
Leonard Jellicoe: p. 214
NASA, Washington DC, USA: p. 10, 95, 127
Nationale Beeldbank, Amsterdam: p. 9, 107, 127, 202, 282, 286
Omega Pharma: p. 305
Penn State: p. 77
Philips Lightning, Eindhoven: p. 151, 267
Pixabay.com: p. 111, 127
Sanyo, Lier, Belgium: p. 156
Science Photo Library: p. 59, 70, 257, 287
Seiko Nederland BV, Schiedam, IAAF: p. 180
Shutterstock: p. 8, 20, 21, 22, 27, 37, 55, 56, 57, 66, 87, 88, 111, 113, 115, 118, 126, 131, 136, 141, 142, 153, 220, 221, 231, 258, 263, 266, 267, 275, 280,295, 306, 311
si-foto.com: p. 274
Starco: p. 241
Tom Haflinger: p. 213
tonyhallas/astrophoto.com: p. 299
Trio: p. 273
UNECE: p. 15
Wan Chi Lau: p. 215
Weems & Plath: p. 87
You Tube: p. 179

Alle rechten voorbehouden. Niets uit deze uitgave mag worden verveelvoudigd, opgeslagen in een geautomatiseerd gegevensbestand, of openbaar gemaakt, in enige vorm of op enige wijze, hetzij elektronisch, mechanisch, door fotokopieën, opnamen, of enige andere manier, zonder voorafgaande schriftelijke toestemming van de uitgever.
Voor zover het maken van kopieën uit deze uitgave is toegestaan op grond van artikel 16b Auteurswet 1912 j° het Besluit van 20 juni 1974, St.b. 351, zoals gewijzigd bij het Besluit van 23 augustus 1985, St.b. 471, en artikel 17 Auteurswet 1912, dient men de daarvoor wettelijk verschuldigde vergoedingen te voldoen aan de Stichting Reprorecht (Postbus 3051, 2130 KB Hoofddorp). Voor het overnemen van gedeelte(n) uit deze uitgave in bloemlezingen, readers en andere compilatiewerken (artikel 16 Auteurswet 1912) dient men zich tot de uitgever te wenden.
© Malmberg 's-Hertogenbosch

AUTHORS:
P. van Hoeflaken
R. Tromp

EDITORS:
K. Gibbs
R. Tromp

WITH HELP FROM:
Th. Smits

TRANSLATION:
M. Wilkinson

ISBN 978 90 345 8354 3

551497

MALMBERG